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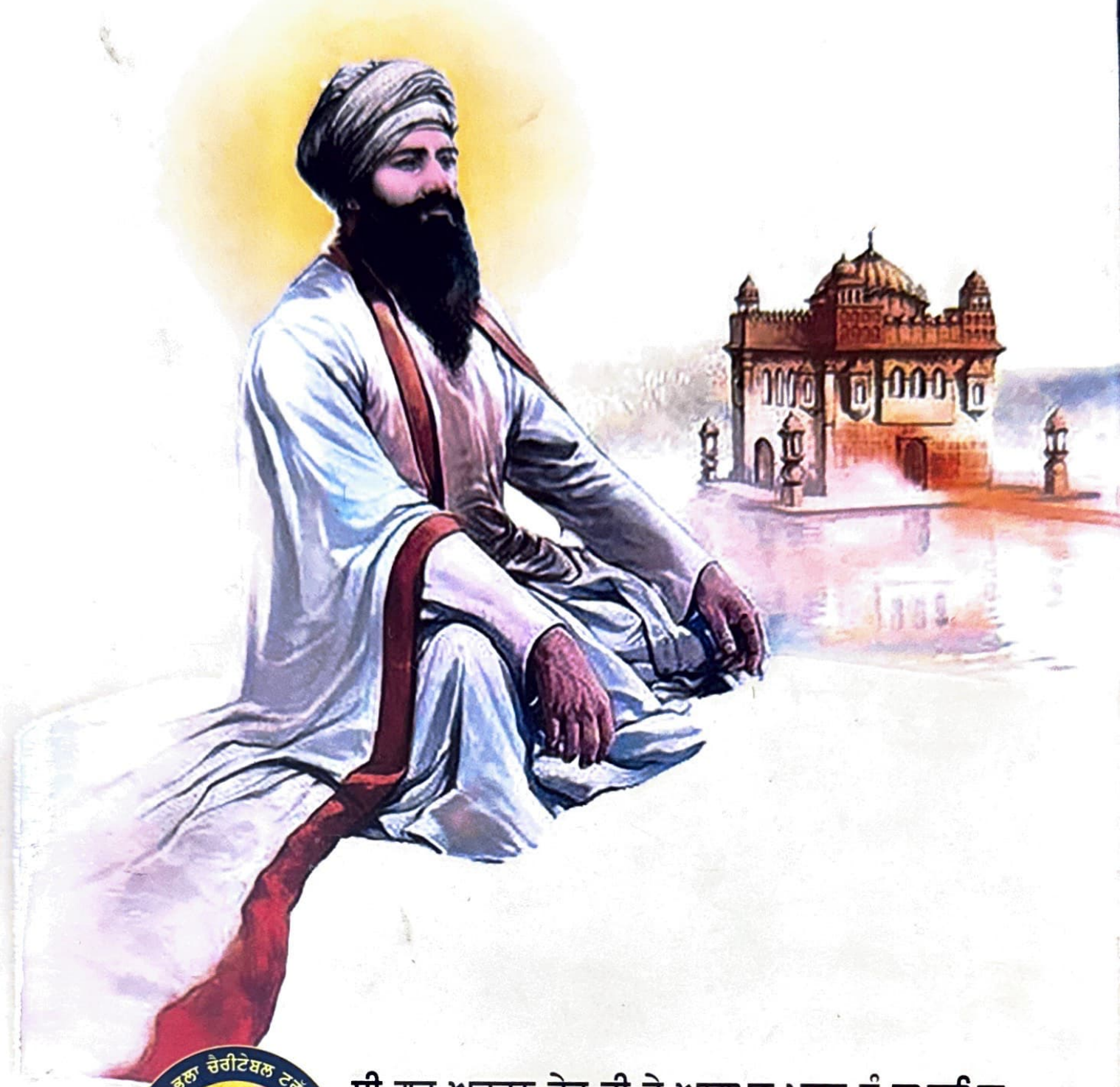

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ਪਬਲੀਕੇਸ਼ਨ ਬਿਊਰੋ

ਸੰਨੀ ਓਬਰਾਏ ਵਿਵੇਕ ਸਦਨ

ਐਡਵਾਂਸ ਇੰਸਟੀਚਿਊਟ ਆਫ਼ ਸੋਸ਼ਲ ਸਾਇੰਸਜ਼, ਸ੍ਰੀ ਅਨੰਦਪੁਰ ਸਾਹਿਬ, ਪੰਜਾਬ

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AN INSIGHT INTO THE EDUCATIONAL OUTLOOK OF SRI GURU ARJAN DEV JI

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Education is a systematic process through which a child or adult gains information, experience, skill, and a positive attitude. It civilises, refines, cultures, and educates a person. Education is the only way to create a civilised and socialised society. Its purpose is to make a person ideal. Every culture values education since it is a cure-all for all ills. It is the secret to solving all of life's issues. In its broadest meaning, education is any act or event that has a formative influence on an individual's intellect, character, or physical ability. Education is the foundation for national growth. Education is one of the most powerful tools for bringing progressive change.

Because to the fast growth of science and technology in the twenty-first century, humans beings are facing unprecedented opportunities and problems in their lives. Every civilisation on the earth is experiencing a moral and ethical values crisis. Exploitation by another human being, religious terrorism, casteism, social indifference, economic inequality, and corruption are just a handful of the numerous societal ills that plague us today. At the moment, the separation of contemporary education from religion has resulted in a belief crisis in nearly every sector of human endeavour. Students' loss of moral principles, character, and discipline has become a source of worry nowadays. Guru Arjan Dev Ji stressed the importance of moral and religious principles. His idea of religion includes everyone in the globe, regardless of religion, caste, colour, breed, or race. A really educated person, in his opinion, is a pious person who is pure in his ideas, words, and acts.

Many outstanding persons dedicated their lives to the development of human life and education. Many people like Lord Buddha, Guru Nam Dev Ji, Guru Ravidas, Guru Kabir Ji, Mahatma Jyoti Rao Phule, his wife

Mata Savitri Rao Phule, Shahuji, all the ten gurus namely:- Guru Nanak Dev Ji, Guru Angad Dev Ji, Guru Amardas Ji, Guru Ramdas Ji, Guru Arjun Dev Ji, Guru Hargobind Ji, Guru Har Rai Ji, Guru Harkrishan Ji, Guru Teg Bahadur Ji, Guru Gobind Singh Ji. Among them was Guru Arjan Dev Ji who is known as a King of martyrs.

Guru Arjan Dev Ji had a strong educational philosophy as well as a philosophy of life. He used education to help the general public grasp his point of view. He discussed the goals of education, curriculum, teaching methods, the role of the teacher, discipline, and the examination system. He had a philosophy, an educational philosophy, pedagogy, and his own problem-solving skills. Education is as ancient as the human race itself. It is a never-ending process of inner growth and development that lasts from birth to death. In a real sense, education serves to humanize people and promote progress, culture, and civilized living. He develops into a human, a socially responsible, moral, and spiritual being through education. Man has become apathetic toward the truth, goodness, beauty, and love that connect humanity with God in this age of science and technology. All of this suggests that the Sikh Gurus had their own philosophy which led to their own way to tackle the worldly problems and their educational solutions too. In their native tongue, they wrote the Gurbani.

The fifth Guru, Arjan Dev Ji, not only pondered the conditions that were in place but also developed solutions to them. Guru Ji created, worked, and lived for the general public. . He developed the philosophical answers as well, all for the good of the people. He established educational institutions in Kartarpur and Amritsar. Shri Guru Granth Sahib was compiled by him. He gathered the 'Bani' of the other five Gurus, fifteen Saints, eleven Bhatts, and four Sikhs, and gave put his seal of authenticity upon it as a PackiBani. It contained a total of 36 scholars, philosophers, saints, and intellectuals of various castes and creeds, collectively known as the 'Bani'. The development of other values along with spiritual emancipation was the central idea of Guru Arjan Dev's philosophy. He compiled Guru Granth Sahib keeping in

view the spiritual theme under different stages as these helped in concentration. He divided the Guru Granth Sahib into stages to aid in concentration while keeping the spiritual theme in mind. In addition to the spiritual theme, education was philosophized as well. Guru Arjan discussed educational philosophy with social philosophy

On August 31, 1518, at Goindwal, Guru Arjan Dev ji, the fourth successor to Guru Nanak ji, was installed as the fifth Guru of the Sikh community. His grandfather bestowed his blessing by saying,

" ਦੋਹਿਤਾ ਬਾਣੀ ਕਾ ਬੋਹਿਥਾ (DOHITA BANI KA BOHITA." Guruship was bestowed on to Guru Arjan Dev ji exclusively on the basis of merit.

The compilation of the Guru Granth Sahib is Guru Arjan Dev Ji's greatest contribution to education. He undertook the enormous task of including the hymns of five gurus, fifteen Bhaktas, four Sikh devotees, and eleven Bhats. He wrote 2218 hymns for the Adi Granth by himself. All of these hymns are set to 30 musical measures by him:

ਉਗਵਣਹੁ ਤੈ ਆਥਵਣਹੁ ਚਹੁ ਚਕੀ ਕੀਅਨੁ ਲੋਆ ॥

Ugvanahu Tei Athavanhu chhu chki Kianu Loa ॥
From east to west, He illuminates the four directions.
– Guru Granth Sahib, Pg. 968

In the quotes from the Guru Granth Sahib above, Rai Balvand claims that Guru Arjan Dev Ji spread the light of knowledge in all four directions through the Guru Granth Sahib.

Guru Arjan Dev Ji believed that the best way to purify one's mind was through education. Man achieves spiritual enlightenment and the dispelling of ignorance through education. Education aids in revealing to man the Ultimate Reality. Such knowledge is the pinnacle of both intellectual and spiritual growth. There is no longer any fear, hatred, greed, or lust when one is in tune with God. Man then lives in an everlasting state of happiness and peace.

According to the Guru, education should be a tool for a person's holistic development, including his or her spiritual, intellectual, moral, social, cultural, and physical growth. Guru Arjan Dev Ji preferred an active lifestyle and discouraged asceticism or living alone. He believed that hard work stimulated the brain, fostered social skills, helped people become independent, and brought people closer to God.

Guru Arjan urged his disciples to live in harmony, peace, and unity. He collected the compositions of numerous saints from a variety of backgrounds and included them in the *Guru Granth Sahib.*

The Guru developed BavanAkhari, a method for teaching the Gurmukhi alphabets to children. These were idioms that elaborated on the teachings of the Gurus in order to help the kids learn the Gurmukhi alphabets.

ਗਗਾ ਗੋਬਿਦ ਗੁਣ ਰਵਹੁ ਸਾਸਿ ਸਾਸਿ ਜਪਿ ਨੀਤ॥

Gaga Gobid Gun Ravhu Sasi Sasi Japi Neet ॥
Chant the Glorious Praises of the Lord of the Universe
with each and every breath; meditate on Him forever.
– Guru Granth Sahib, Pg. 254

The study of the *Guru Granth Sahib* was encouraged by Guru Arjan Dev Jiamong his students. He supported his followers' literary talent being developed. This, in his opinion, was one method of immersing oneself in the memory of God. For a thorough educational development, he believed that understanding the scriptures of other religions was also crucial.

Guru Arjan Dev Ji recognized the value of commerce and trade.

He added mathematics to the curriculum with that in mind. In Kandahar and Kabul, his adherents traded horses, and in Amritsar, which later developed into a significant commercial hub, he supported the thriving 52 trades.

The fifth Guru lived before the invention of the printing press. The public was given copies of *Guru Granth Sahib* that had been

handwritten. Thus, in order to produce copies of the *Granth Sahib* of the highest possible quality, Guru Arjan Dev Ji promoted the practice of calligraphy.

The fifth Guru was acutely aware of the Mughals' lack of proficiency in the language of peace. He encouraged his son, Guru Hargobind, to join the military so that, when the time came, he ould deal with the tyrants bravely.

In order for kids to learn more about Sikh culture and tradition, Guru Sahib also encouraged festival celebration, attendance at significant occasions, and fair organization.

Guru Arjan Sahib Ji held that ignorance among people can only be eradicated and the true meaning of life realized through the efforts of the Guru. The guru aids man in choosing the noble path and freeing himself from the cycle of reincarnation. The guru aids in clearing peoples' minds of ignorance. The Guru bestows the most priceless wealth on the populace by illuminating them with the truth. When the Guru initiates a person to the spiritual path without making any distinctions based on caste, color, or creed, any anxiety, fear, or doubt that was present in the person's mind is removed.

The Guru gave the *AdiGranth's* written words the status of the Guru because he recognized the value of the written word. He did not downplay the significance of surrounding himself with religious people. He was aware that such company rids one of ignorance, destroys ego, and inspires one to live a pure life.

A close examination of Guru the'bani'of Arjan Dev Ji reveals that a disciple never ceases to be in awe and love for his Guru. A true disciple is one who fully understands what the Guru is saying. He is devoted to his Guru's spiritual teachings. He pursues the reality. He participates in sewa, or serving the community. A disciple holds the Guru in the highest regard. He completely gives himself over to the Guru. There will soon be no distinction between the disciple and the guru.

Guru Arjan Dev Ji encouraged his followers to live a disciplined lifestyle. He urged them to exercise discipline over their bodies, minds, and spirits. He suggested that they begin each day with kirtan and katha, go to work, and return to the Gurudwara in the evening for kirtan, katha, and discussions and debates about matters affecting the community. A spirit of inquiry and exploration that is so crucial to the growth of man as an awakened being was carefully promoted.

Guru Arjan Dev Ji refers to 'Brahm-Gaini' in *Sukhmani Sahib.* He claims that 'Brahm-Gaini' is someone who has passed every test that God has set. A person in this position has attained spiritual enlightenment. Mammon has no effect on 'Brahm-Giani'. He is sinless and has love for everyone in his vicinity. In every circumstance, he maintains his composure and composure. 'Brahm-Gaini' is endowed with divine wisdom. He is gentle and modest. Nobody can comprehend his worth or evaluate his greatness.

By using real-world examples, Guru Arjan Sahib demonstrated organizational skills to his followers.He assigned his followers, known as Masands, the task of obtaining 'Daswandh' or voluntary contributions, to be used for community welfare initiatives.

On account of the sacred compositions preserved here in the form of Guru Granth Sahib installed at Darbar Sahib and the presence of scholars, artists, blessed souls and sages in the town, sessions for discussion and dialogue , lectures and expositions were in plenty , and centres for learning and training of all types were set up . The art of architecture and classical music (kirtan), the transmission of sacred knowledge and the proficiency in weapon handling, all continued to advance simultaneously. When the Harmandir Sahib was being built, the Sikh community began to perform sewa, or selfless service. These initiatives boosted the Sikhs' sense of equality at gatherings and in the dining hall by removing differences and hastening the process of communal cohesion. As cities like Tarn Taran were established and the

service to the lepers began there, the Sikh community gathered there to celebrate holidays and go to fairs.

Like his predecessors, Guru Arjan Dev Ji was acutely aware of the significance of women's contributions to society. He believed that women needed to engage in activities outside the home as well. He saw them as a resource for both her kids and the community at large. He was in favor of handwritten copies of the Gurbani being made and of women reading it in Gurudwaras. He established educational facilities for women and girls that were connected to Gurdwaras.

Through his martyrdom, Guru Arjan imparted the greatest lesson to humanity. His followers discovered that no force on earth can dissuade a man from his spiritual beliefs. On the one hand, the Sikh race was soon going to evolve into a martial race. He helped the Sikhs understand that those who are truly devoted to God cannot be hurt:

ਜਿਸੁ ਮਨਿ ਵਸੈ ਪਾਰਬ੍ਰਹਮੁ ਨਿਕਟਿ ਨ ਆਵੈ ਪੀਰ ॥

Jis Man Vasai Parbraham Nikat na Avai Pir ॥
Pain does not even approach that person, within whose mind God abides.

– Guru Granth Sahib, Pg. 1102

Among his followers, Guru Sahib fostered a deep faith in the Almighty. The Sikhs became fearless and loving because they firmly believed in the all-loving, fearless God. As a result, the Sikhs were always prepared to defend the truth, humanity, and fight against the tyrant's atrocities.

Guru Arjan Ji was a renowned academician. He compiled the AdiGranth, the holy books of the Sikhs. In an effort to make the texts as accessible as possible to as many people as possible, he also included it in hymns that honored Muslim saints. He also finished the renovations that Guru Ram Das started on the Amritsar Golden Temple. They built the temple with four doors facing in four different directions to show that they welcomed people into the temple from everywhere and from all

backgrounds. The murder of Guru Arjan was ordered by the Mughal Emperor Jahangir. He did this because he believed Guru Arjan ought not to have incorporated Islam into the Sikh holy book. Guru Arjan is renowned a King of martyrs. He was tortured in peace while undergoing various forms of punishment. A follower feels a connection to their beloved. They wanted to stay forever, and being apart from their Beloved hurts them. Although devotees appear uneasy while seeking their beloved, they find peace by memorizing their beloved.

To conclude, the educational outlook of Guru Arjan Dev Jidemonstrates that he applied meticulous standards to give the scripture its unique form in terms of both content and style. The *AdiGranth* has an internal unity because the theological elements of its texts are consistent with their metrical, poetic, and linguistic structures. The final text of the scripture was also largely under the control of Guru Arjan, and some key elements of his editorial stance are evident in the rédaction procedure itself.

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Advanced Functional Materials for Optical and Hazardous Sensing

Synthesis and Applications

Springer

Metallopolymer-Based Sensor for Hazardous Gases

Narender Budhiraja, Monika Tomar, and S. K. Singh

Abstract The hybrid structure of metallopolymers has garnered significant attention from researchers and the scientific community worldwide due to its multifunctional, biodegradable, and highly proficient elastic-tensile properties. Their periodic structure and innovative architecture make them potentially suitable for the synthesis of low-cost energy harvesting, sensing, and optoelectronics devices. Furthermore, their larger surface area and homogeneity enhance their physicochemical properties, making them ideal candidates for rapid response, quick recovery, low power consumption, and, therefore, superior sensing materials compared to other options. Hazardous gases such as nitrogen oxides (NO_x), sulfur oxides (SO_x), methane (CH_4), and carbon monoxide (CO) pose life-threatening risks and must be detected at an early stage of leakage. Metallopolymer-based gas sensors play a vital role in effectively detecting these gases. In this chapter, we will discuss the current achievements and upcoming challenges related to metallopolymers as functional materials for advanced gas sensing applications in environmental monitoring.

Keywords Energy harvesting · Sensing · Response · Metallopolymer

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1 Introduction

Globally, one of the foremost challenges confronting the scientific community is the significant increase in the emission of hazardous gases. With the growth of civilization, industrialization, and the widespread adoption of fuel-based transportation, there has been a substantial rise in the release of harmful gases, including carbon dioxide, carbon monoxide, sulfate-based gases, and other volatile organic compounds. These emissions have deleterious effects on the global environment and pose a significant threat to living organisms. Consequently, this issue has garnered the attention of scholars worldwide and has spurred them to search for suitable sensor materials for the early-stage detection of hazardous gases. Real-time monitoring of hazardous gases is imperative, and this can only be achieved using reliable gas sensor devices. These sensors should be strategically deployed in industries, refineries, medical diagnostic facilities, and sectors related to space and defense. The primary objective is to ensure the precise and accurate detection of harmful gases, enabling timely interventions to prevent any potential tragedies resulting from gas leaks.

Various conventional gas sensors based on metals, metal oxides, and ceramics have been used for several decades for this purpose [1]. Recently, metallopolymers have emerged as potential candidates for sensing devices. These remarkable metallopolymers find applications in various important fields such as solar cells, sensors, polymer-based LEDs, memory devices, biomedical applications, catalysis, and more [2], as listed in Fig. 1. Metallopolymers are innovative hybrid materials in which metals are incorporated into an organic polymer matrix. This incorporation of inorganic elements into an organic matrix imparts significant advantages, making them superior to conventional gas sensors based on other materials [3, 4]. Historically, the first synthesized metallopolymer, Poly(vinyl ferrocene), was discovered by Arimoto et al. in 1955 [5]. Despite their fascinating and novel properties, limited research has been conducted on these hybrid structures due to a lack of suitable characterization methods. This factor led to their relative obscurity until the late 1990s. With advancements in synthesis methods, control techniques, and the development of sophisticated analytical instrumentation facilities, the study and fabrication of polymer-based materials have become increasingly smooth [3, 6–8]. For example, in 1990, Forster et al. employed a stepwise polymerization route for the synthesis of metallopolymers consisting of osmium and ruthenium, which were characterized using UV–Vis spectroscopy [9]. Subsequently, the incorporation of metals into polymer hybrid structures emerged as a significant branch of polymer science in the twentieth century. In 2005, Athawale et al. published a study on PANI/Pd nanocomposites formed through the reflux process [10]. They exposed these nanocomposites to various aliphatic alcohol vapours, including isopropanol, and observed that PANI/Pd nanocomposite-based sensors exhibited high sensitivity, exceptional selectivity, and rapid response to methanol vapour. Metallopolymer-based gas sensors, owing to their enhanced optoelectronic properties, appear to outperform conventional gas sensors. Furthermore, doping metal nanoparticles into the polymer matrix enables

room-temperature adsorption and desorption of reducing gases such as H_2, CO, and NH_3 [11–15]. Compared to other types of gas sensing devices, metallopolymer-based gas sensors offer the versatility of multiplex detection for various hazardous gases [8]. It has been demonstrated that the composition, size, and shape of the metal nanophase significantly influence the electrical conductivity and other properties of the composites used in gas sensor devices [16]. Hong et al. [17] created nanocomposites of PPy/Pd in 2009 by initially gas-phase polymerizing pyrrole and subsequently reducing Pd ions in a solution. They discovered that the structure of the composite membrane is significantly influenced by factors such as the concentration, absorption, and proportion of reactants, the polymerization reaction time, and the quantity of polymer additives. Subsequently, they calculated the nanocomposite's sensitivity to NH_3 detection. In 2013, Zhang et al. [18] implemented a one-pot method to produce PPy/Gold nanocomposites with uniformly distributed gold NPs on PPy. The size of the gold NPs was significantly reduced by the addition of lysine. Another crucial point to consider, aside from NP size, is NP concentration. Choudhury [19] synthesized PANI/Ag nanocomposites in 2009 using an in-situ chemical polymerization method at concentrations ranging from 0.5 to 2.5 mol% Ag. Their research revealed that the concentration of silver NPs had a substantial impact on the sensitivity and response/recovery time of the PANI/Ag nanocomposite-based sensor. Furthermore, the dielectric and conductivity properties of PANI/Ag nanocomposites were greatly superior to those of pure PANI, with AC conductivity being approximately 100 times higher. The PANI/Ag nanocomposites-based sensors also exhibited faster and more reversible ethanol detection capabilities. In general, metals often exist in the form of NPs in metal-conducting polymer nanocomposite systems, whereas conductive polymers are typically in the form of thin films. However, quantum-confined metal-incorporated polymer structures in one or two dimensions can also benefit from their high surface-to-volume ratio to enhance the performance of gas sensors [20–22].

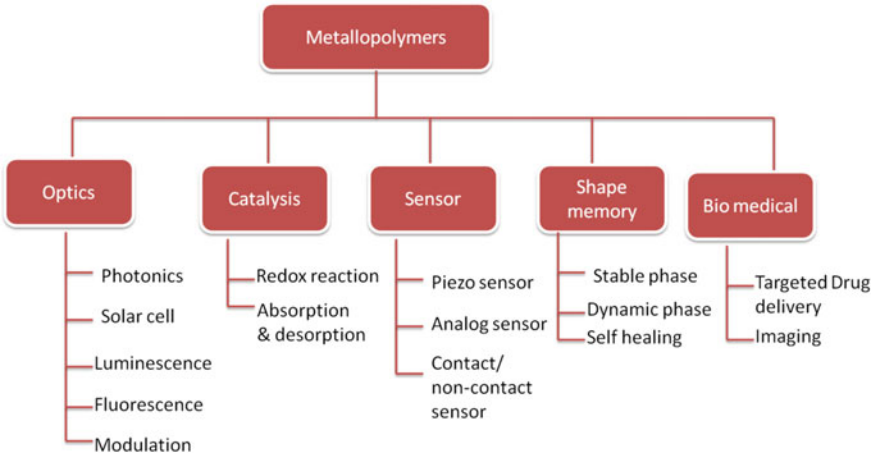

Fig. 1 Illustration of various applications of metallopolymers and their respective field

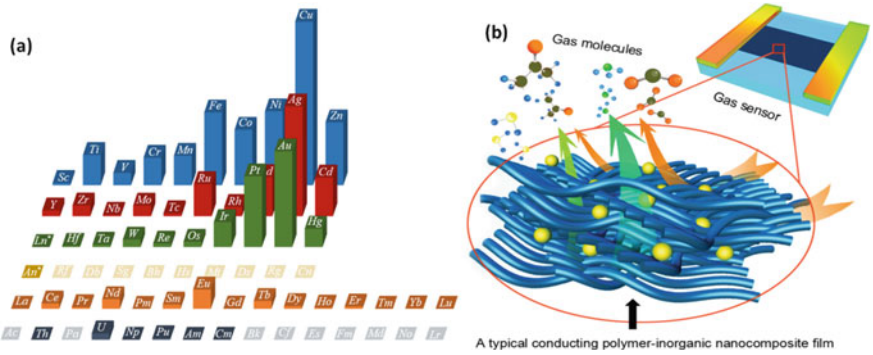

Fig. 2 **a** Schematic representation of d-and f-group metal utilized with polymers and their rate of publication. Reprint with permission from [2]. Copyright (2021) Elsevier. **b** Representation of polymer-inorganic nanocomposite film for gas sensing, reproduced from [16]. Copyright (2020) Taylor & Francis

The market for gas sensors is currently estimated to be worth $500 million annually and is expanding at a 10% annual rate [23]. Furthermore, in Fig. 2a, various d and f-block metals incorporated into a polymer matrix are revealed, along with their publication rates. Additionally, in Fig. 2b, there is a schematic representation of a typical inorganic-polymer nanocomposite film for gas sensing purposes.

Furthermore, the market's recent expansion has been facilitated by smaller gas sensors based on metallopolymers. These sensors have contributed to reducing the cost per unit of sensors.

2 Classification of Hazardous Gases

Hazardous gases can pose significant risks to human health and the environment due to their toxicity, flammability, noxious properties, or corrosive nature, which depend on their specific characteristics and concentration levels. These gases can have detrimental effects, directly impacting the neurological and cardiovascular systems of living organisms [24]. Hazardous gases and vapors, including but not limited to toxic industrial gases (such as NH_3, H_2S, CO_x, NO_x), organic volatile compounds, and radioactive species, pose serious threats to both the environment and human health. The primary sources of these dangerous emissions into the environment are anthropogenic and encompass industrial facilities, power plants, domestic sources, and the burning of fossil fuels. In Fig. 3, a classification of hazardous gases is presented, emphasizing the importance of early detection to prevent accidents. This chapter will delve into various categories of hazardous gases for a comprehensive understanding of their risks and implications.

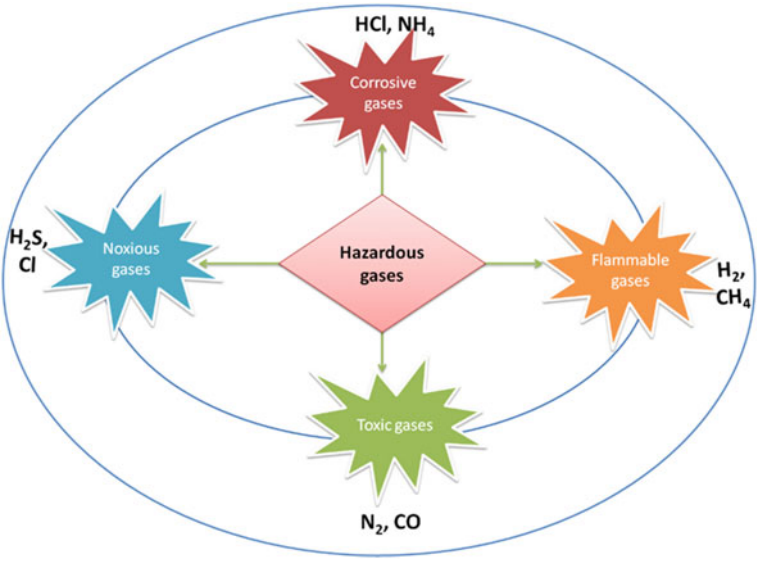

Fig. 3 Schematic representation of types of various hazardous gases

2.1 Toxic Gases

Asphyxiants or toxic gases for example carbon monoxide are dangerous and can lead to death by various mechanisms, including the depletion of oxygen in the environment. These gases interfere with the body's ability to access oxygen, ultimately resulting in fatalities.

2.2 Corrosive Gases

Corrosive gases are harmful as they can directly impact human tissues. Additionally, these gases can damage metals and other construction materials. Examples include hydrochloric acid, ammonia, and sulfur dioxide, among others.

2.3 Flammable Gases

When flammable gases are combined in the proper ratios with air or oxygen, they can become explosive. Consequently, gas mixture explosions can occur, posing a significant threat to the safety of public property and individuals working in the

chemical industrial sector. Hydrogen, methane, propane, ethylene, acetylene, and ethane are a few examples of flammable gases.

2.4 Noxious Gases

Noxious gases, such as hydrogen sulfide, sometimes referred to as sewage gas, comprise a group of hazardous substances. Hydrogen sulfide is a colorless, highly flammable gas that poses significant dangers. Even in small quantities, it emits a strong odor resembling "rotten eggs." These gases find prominent usage in various industrial processes, including mining, pulp and paper manufacturing, oil and gas refining, and other industrial operations. In contrast, they can also occur naturally in environments like sewers, volcanoes, and pits. The primary sources of these types of gases, as indicated by [25], are refineries, power plants, petrochemical processes, and effluent treatment facilities.

3 Categories of Metallopolymer

Wolf proposed a classification system for metallopolymers based on the positioning of metal complexes within the polymer matrix. This classification includes three categories: Type I, Type II, and Type III, which are determined by the method of incorporating metals into the hybrid structure [26].

In the classification of Type-I metallopolymer, a metal complex is attached to the polymer backbone through the association of an alkyl group. This attachment is made under the condition that the physiochemical properties of the metal group must be identical to those of the polymer matrix. Figure 4a represents a Type-I metallopolymer, which consists of an inorganic metal compound linked to the backbone of a polymer block.

In the Type-II metallopolymer classification, the metal complex and the polymer backbone are electronically coupled to each other, as depicted in Fig. 4b. These hybrid structures exhibit both feasible and tunable properties due to the presence of a redox-active system within the organic–inorganic framework. Bipyridyl ligands are particularly well-suited for attaching metal ions to the hybrid polymer backbone and play a crucial role in facilitating strong electronic interactions between the metal center and the bipyridyl groups within the hybrid polymer backbone.

For the Type-III metallopolymer category (Fig. 4c), the metal center is directly bonded to the hybrid polymer backbone. In this arrangement, dominant electronic interactions occur between the metal group and the polymer backbone. Moreover, the metal center can facilitate intramolecular charge movement. These metallopolymers are attractive materials for energy harvesting devices, where high charge carrier mobilities are one of the fundamental requirements.

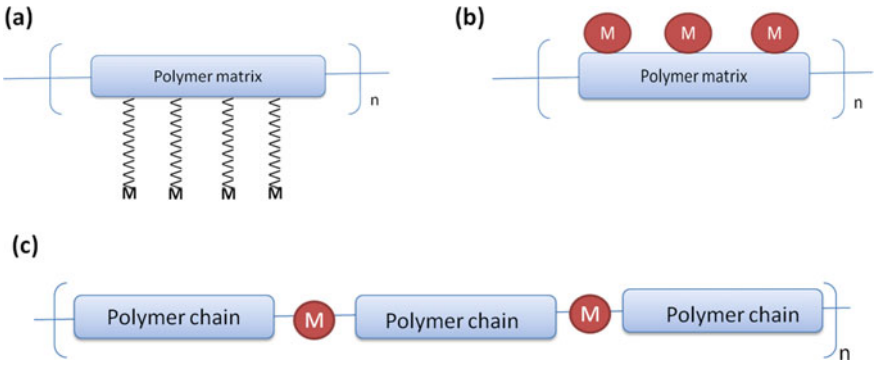

Fig. 4 **a–c** Schematic diagram of Type I, II, and III metallopolymer

4 Characteristics of Metallopolymer-Based Gas Sensors

4.1 Degree of Dispersion

The majority of the currently used methods for creating metallopolymers are based on condensation and dispersion techniques [27]. In the primary instance, phase change results in the spontaneous assembly of a polymer matrix from individual molecules. The second approach posits that metallopolymers are formed during the dispersion (or breakdown) of a macroscopic phase. These methods enable the production of metal-incorporated polymers with varying degrees of dispersion for gas sensing. Furthermore, the cost of any material, from its raw materials to its final hybrid structure, is influenced by its processability. The processability of metallopolymer-based gas sensors may be affected by the cost of producing nanocarriers and the availability of raw materials for enzyme carriers.

4.2 High Mobility and Larger Surface Area

The mobility of metallopolymers is exceptionally high, which results in a significant number of charge carriers available for interaction when exposed to target gases. Furthermore, metallopolymers offer a substantial advantage over conventional materials due to their larger surface-to-volume ratio [2]. These characteristics render them highly suitable candidates for gas-sensing devices.

4.3 Porosity

Depending on the available coordination sites on the metal and their position within the organic matrix, high porosity can be achieved in these hybrid structures. Pores play a crucial role in defining the matrix's capacity for stabilization. These pores serve as conduits, allowing nanoparticles or their precursors to infiltrate the polymer bulk. Additionally, the presence of nanoparticles may induce structural distortions in the polymer. Several parameters can influence porosity, specific surface area, and pore radius [28].

4.4 Nucleation

The ratio between nucleation and crystallization rates plays a critical role in determining the ultimate hybrid morphology during the synthesis of metallopolymer, which is a thermodynamically driven process. The high energy of the particles produced can be attributed to the presence of uncompensated linkages on many surface atoms. By calculating their critical size and identifying controllable variables, the thermodynamic method facilitates the analysis of the conditions leading to the formation of nuclei in the new phase. The distribution function of metal-incorporated polymer structure sizes is often defined using kinetic equations, which are frequently employed to elucidate experimental data [29].

4.5 Basic Aspect of Gas Sensor

The presence of a particular gas in the atmosphere is detected by a device known as a gas sensor. Such devices consist of a sensing layer made from a prepared material in the form of a thin film and can detect alterations in resistance when exposed to hazardous gases. This type of sensor is primarily referred to as a chemoresistive gas sensor [30]. The change in resistance results in electronic variations, which occur during the interaction between the sensing layer and the hazardous gas. Figure 5 depicts a schematic of an Interdigital Microelectrode (IDE) comprising a polymer matrix with incorporated Co metal for NO gas detection.

In Fig. 6, a general assembly of a gas sensor is shown, consisting of a transducer, a receptor, and a responsive circuit. Broadly, gas sensors are categorized based on the transducer used and subcategorized by the type of thin sensing materials [31].

$$\text{Gas Response (S)} = \frac{R_a}{R_g} \text{ (for reducing gases)}$$

Or

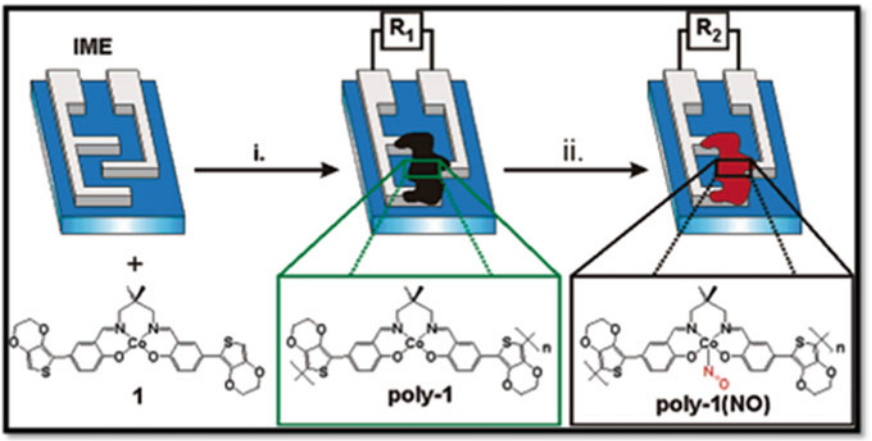

Fig. 5 Schematic illustration of the fabrication of conducting metallopolymer/electrode devices: (i) electropolymerization of Co containing monomer (1) across interdigitated microelectrodes (IME), (ii) chemoresistive response to NO gas exposure, reproduced from [31]. Copyright (2006) American Chemical Society

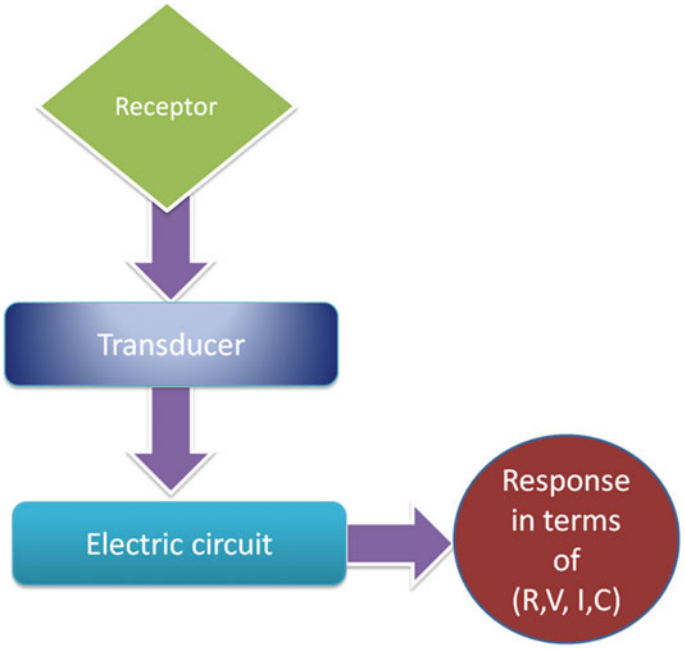

Fig. 6 Schematic setup of transducer and sensing material with electric components

$$(S) = \frac{R_g}{R_a} \text{ (for oxidizing gases)}$$

Furthermore, on a logarithmic scale, there exists a linear relationship between Rg and the pressure of hazardous gases, a phenomenon known as the power law [32]. A distinct adsorption equilibrium forms when thin metallopolymer films are exposed to gases other than environmental reference air. In this equilibrium, some of the new gas components (analytes) in the carrier gas diffuse into the film. When the analyte exits the gas phase, this process can be reversed, as illustrated in Fig. 7. The addition of analyte gas during its presence can significantly alter the physical, electrical, optical, and color properties of the film. This includes changes in dielectric constants and colors. Besides, the operating temperature plays a crucial role in the reliability of response and recovery times. With increasing temperature, the response and recovery times are extended when exposed to reducing gases. Conversely, when interacting with oxidizing gases, the gas response decreases with increasing temperature. This reverse behavior occurs in oxidizing gases due to variations in the energy band resulting from gas molecule adsorption on the surface [33]. There is another important classification of gas sensors where capacitance and applied voltage are the main factors influencing gas sensing behavior. Typically, solid dielectric materials and electrolytes are used in this context [24]. For gas-phase testing, metallopolymer films are deposited over interdigital Pt or Sn electrodes using methods such as sputtering, sol–gel, or chemical vapor deposition (CVD) [31]. Figure 8 illustrates schematic methods for the formation of metallopolymer films through chemical processes.

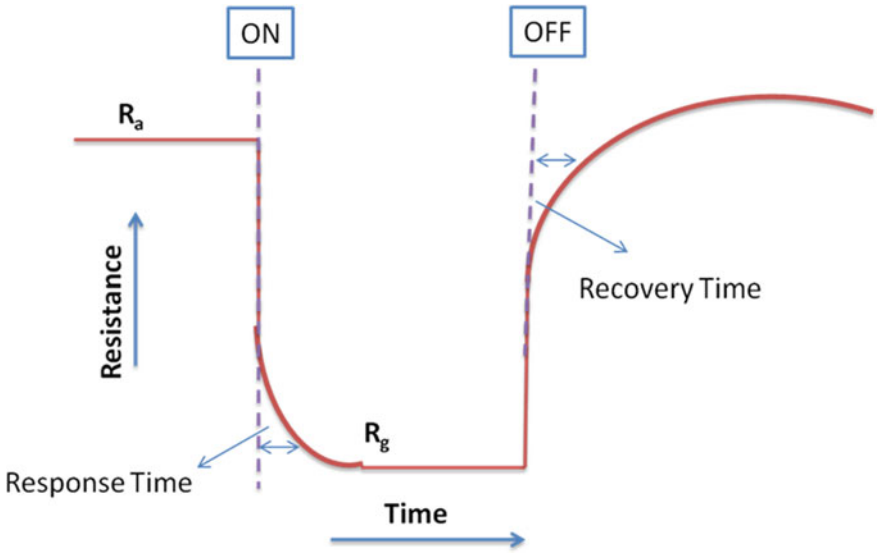

Fig. 7 Schematic illustration of recovery and response signal on exposure to gas

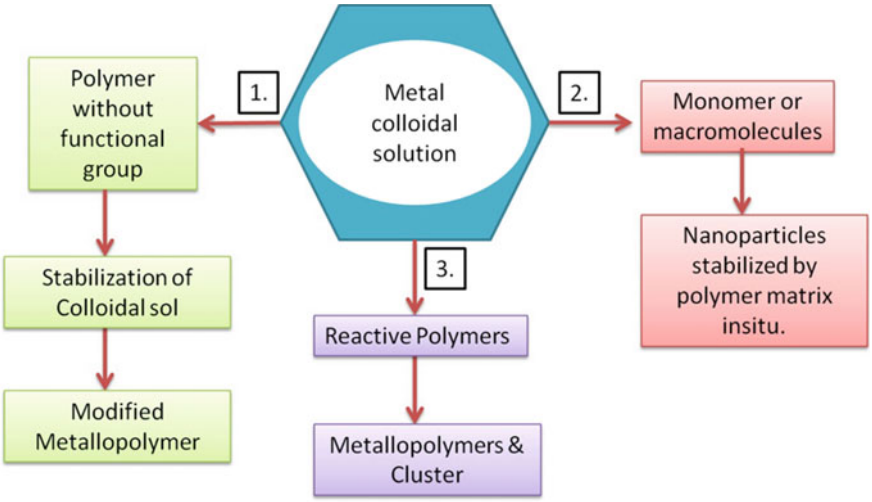

Fig. 8 Illustration of chemical routes for the synthesis of metallopolymers

The synthesis routes described above represent facile approaches for fabricating metallopolymers intended for gas-sensing purposes. The final hybrid structure's grain size depends on several factors, including the choice of the host polymer matrix, the selection of linkers, and the specific metal ion chosen for incorporation. Furthermore, it is possible to easily adjust the cluster particle size of the metallopolymers and enhance their recovery and response characteristics by modifying the reaction conditions and altering the associated ligands.

5 Concept of Stabilization

The stabilization of metals using hybrid polymers involves consideration of several key factors, including the dependence of metal nanoparticles in a liquid medium, the settling capability of the polymer network, and the adsorption of polymers onto metal complexes. The high chemical activity at metal–polymer interfaces can lead to numerous spontaneous reactions [34]. Polymer colloidal science, in its current state, encompasses the stabilization of metal nanoparticles by high-molecular-weight compounds, representing a significant subfield. This area of study delves into the development of highly sophisticated interfaces within dispersed systems, examining their kinetic and aggregation stability, surface topographical phenomena arising from interactions, and the adsorption of polymers from liquids onto solid surfaces. Colloidal solutions containing both metal and polymer are characterized by relatively low stability, primarily due to their larger particle sizes and considerable free surface energy [35]. Solutions with metal-incorporated polymers achieve stability through

one of two mechanisms. Kinetic stability pertains to the ability of the system to resist gravitational forces. As particle size increases, the sustainability of such structures significantly decreases. When the rate of particle settling under the influence of gravity is so slow that it can be ignored, the system is considered kinematically stable. Another form of stabilization is referred to as aggregate stability, which concerns the system's capacity to maintain a diverse range of particle sizes [36]. This type of stability is associated with the capacity of nanoparticles to form large aggregates and adsorb low-molecular-weight ions from solutions onto their surfaces, leading to the formation of an adsorption layer. Metal-incorporated polymer colloidal solutions are broadly categorized into lyophobic and lyophilic types. Lyophilic systems are thermodynamically stable, characterized by negative Gibbs free energy changes. Electrostatic (charged) stabilization is a conventional method for achieving kinetic stability in lyophobic particles. These processes provide stability by creating a repulsion potential that exceeds the energy of colloidal particle aggregation [37]. The stabilization process of metal complexes by polymers can be elucidated by the "molecular solder" hypothesis, also known as adhesive interactions between constituent components. The structural and mechanical aspects of the sustainability of dispersed coagulation structures are fundamental to this theory. The degree of steric stabilization varies as structures are formed, ranging from those with only adsorption layers to those covering the entire volume of the microemulsion. Polymer layers begin to interact when two metal nanoparticles surrounded by adsorbed soluble polymer chains approach each other at a distance smaller than the average thickness of the adsorption layers. In most cases, this interaction results in repulsion and steric stabilization. Efforts have been made to consistently define the nature and quantify the magnitude of this steric stabilization. Typically, this issue is examined in terms of how the Gibbs free energy changes when two molecules, initially at infinite distances from each other, approach each other closely while being coated by an adsorbed polymer layer. Adsorption of polyelectrolytes is a more intricate process compared to that of nonpolar polymers. Two crucial factors in determining the extent of polyelectrolyte adsorption on the charged surface of a nanoparticle are the degree of polyelectrolyte screening and the charge density on the hybrid matrix's surface. The intrinsic characteristics of colloidal particles in a solution play a significant role in reducing specific electrolyte adsorption. Polyelectrolytes can achieve both charge and steric stabilization, adding complexity to the process. Several theoretical frameworks have been proposed to elucidate the mechanism of metallopolymers' stabilization by polyelectrolytes. For example, researchers have examined the influence of homopolymer-based polyelectrolytes at various low-molecular-electrolyte concentrations in liquid [38]. Numerous models have explored the stabilization of metal surfaces by charged monomer units and uncharged block copolymers in the presence of a preferential fluid. These investigations have considered the nature of the liquid and the extent of low-molecular substance adsorption on the metal surface [39]. Silbert et al. [40] have researched polyelectrolyte and uncharged block-copolymer adsorption, focusing particularly on non-selective solvents [41].

5.1 Growth of Metal Incorporated Polymers

Inhomogeneities and different phases are generated at the micro level during the manufacturing of metal-polymer composites through a series of intricate physicochemical reactions. These processes have been extensively studied using various metal-polymer systems, including triplet systems and those containing bimetallic elements [27]. Preliminary polymer formulation plays a pivotal role in the preparation of structurally advanced materials. It involves the utilization of a polymer hybrid matrix with molecularly distributed metal salts. Nevertheless, the formation of complex structures, chemical metal compounds, and other metal complexes, along with chelate cycles of varying compositions involving polymer functional groups, is a critical factor that influences the degree of interaction between the polymer and the metal.

5.2 Self-assembly of Metallopolymers

Over the past few years, there has been significant research focused on the self-assembly of polymers. Consequently, researchers have designed and synthesized several diblock and triblock copolymers, closely examining their hybrid structures [42]. The fact that most metal complexes carry a charge can facilitate the self-assembly mechanism [43]. Moreover, the introduction of heavy metal ions can enhance their contrast properties. Table 1 presents various self-assembled metallopolymers investigated by researchers. Numerous metals, including Ni, Ru, Pd, and Au, among others, are incorporated into the polymer matrix to develop these self-assembled metallopolymers.

5.3 Ligands

By adjusting the metal ion or pH of the system, metal-ligand (M-L) bonds provide a wide range of adaptability in terms of bond strength and binding kinetics, leading to the development of polymers with controllable mechanical properties. This capability enables the synthesis of metallopolymers using various extensively studied M-L pairs [56]. In recent years, numerous supramolecular metallopolymers have gained widespread use as functional materials with promising features. In Table 2, we present some common ligands and their associated metallopolymers.

Table 1 Development of self-assembled metallopolymers and their investigation by various researchers

Serial number	Research group	Self-assembled metallopolymer	Reference
1	Guillet et al.	Ni@ PEG/PS	[44]
2	Mugemana et al.	Ru@ PEG/PS	[45]
3	Yamada et al.	Pd@MEPI	[46]
4	Mohd Yusoff et al.	Pd@KAPs (Ph-PPh3)	[47]
5	Weck et al.	Pd@PS (polymethacrylamide)	[48]
6	Liu et al.	Pd@OAC	[49]
7	Karimi et al.	Pd@NHC/MCOP	[50]
8	Peris et al.	Au@tris(N-hetrocyclic177carbene)/acetylide	[51]
9	Jiang et al.	Pd@ZIF-8	[52]
10	Kajiwara et al.	Ru@PCP	[53]
11	Xu et al.	Au@UIO-67	[54]
12	Elmas et al.	Pt@PGM	[55]

Table 2 Various Ligands and Associated Metallopolymer Studied

Serial number	Ligand	Metallopolymer	Reference
1	Phenol	V^{3+}, Fe^{3+}, Al^{3+}@3,4-dihydroxyphenylalamine	[57]
2	Carboxylic acid	Zn@polydimethylsiloxane	[58]
3	Carboxylic acid	Al@polysiloxane	[59]
4	Pyridine	Zn(II)@diiminopyridine	[60]
5	Terpyridine	Cd(II)@2,2,6,terpyridine	[61]
6	Pyridine-dicarboxamide	Fe(II)@PDMS/PDCA	[62]
7	Azoles	Co(II)triazole pyridine	[63]
8	Urethane	Cu(II)@dimethylglyoxime	[64]

6 Gas Sensor Based on Metallopolymers

6.1 Metallopolymer for Detection of LPG

In-depth research on the frontal polymerization of low-mass molecules, specifically compounds such as butyl or methyl methacrylate/methacrylic acid in the condensed phase, was conducted by Singh et al. in 2012 [65]. The Screen-Printing method was employed to fabricate thick films of synthesized metallopolymers, which were then examined for their ability to detect LPG gas. It is essential to closely investigate the growth of effective and selective LPG sensors tailored to cobalt complexes, as metals within the cobalt family exhibit a high degree of selectivity for LPG sensing.

Thanks to their unique physicochemical properties, materials featuring nanoscale metal particles supported by a polymer matrix have garnered significant attention in recent years. These systems are particularly intriguing for sensing applications due to their high concentration of surface metal atoms in nanosized particles, offering the ability to modify the sensing properties by adjusting their size and surface morphological structure. The proposed mechanism involves the displacement of adsorbed oxygen ions through the formation of water. When LPG molecules interact with the adsorbed oxygen ions on the surface of the synthesized metallopolymer films, combustion products, such as water, are released, resulting in the development of a potential barrier to charge transport. Initially, the surface lacks water vapors, causing environmental oxygen to rapidly adsorb into the dry pores. As the sensor surface adsorbs environmental oxygen, water vapor condenses inside the pores, facilitating the formation of a Schottky barrier. Due to its rapid reaction and recovery times, high sensitivity, and stability, Co/PAAM appears to be a significant metallopolymer for LPG sensing at ambient temperatures, as reported by Singh et al. and other researchers [66].

6.2 Metallopolymer for Detection of Ammonia Gas

A crucial aspect of preserving the environment and human health is the measurement and detection of ammonia in the air. Ammonia is easily detectable by the human nose due to its strong odor. It is estimated that the lower limit at which humans can detect ammonia through smell is approximately 55 parts per million (ppm). However, ammonia can still irritate the skin, eyes, and respiratory system at concentrations below this threshold. Therefore, it is essential to utilize highly sensitive instruments for the identification of such substances [17]. Researchers, led by Naidji et al. [28], have developed a metallopolymer by electropolymerizing a homoleptic Ru(II)-terpyridine complex consisting of pyrrole heterocycles. This process results in the creation of a thin polymer coating on the electrode's surface. Metal-containing polythiophenes, polyselenophenes, or polypyrroles with in-chain terpyridines are excellent choices for manufacturing these types of sensor devices because they are straightforward to produce and can be polymerized onto electrode surfaces. Furthermore, in a study by Lou Lan et al. [67], a metallopolymer based on hydroxyapatite (HA) treated with gold nanoparticles was developed for ammonia gas sensing. This involved creating a tube-like HA structure and incorporating gold nanoparticles through a hydrothermal process. The gas sensor's response remained high, even at smaller concentrations such as 50×10^{-6}, with a sensitivity as high as 70.8%. Additionally, Park et al. [68] conducted research on NH_3 chemical sensors based on composites of Ag metal and PEDOT nanotubes. They varied the concentration of $AgNO_3$ from 5 to 40%, resulting in varying concentrations of silver nanoparticles. The Ag/PEDOT nanotube sample with a 5% concentration

exhibited the highest sensitivity and the lowest detection range for NH_3. Furthermore, Ag nanowires were employed as a support structure and combined with one-dimensional-nanostructured PANI to create a complex material with a hierarchical network structure for NH_3 detection [69]. The sensitivity of this material increased linearly with rising NH_3 concentrations, which could be as low as 5 ppm. Hierarchical PANI/Ag nanocomposite-based films demonstrated superior selectivity to NH_3 compared to particle-like PANI films.

6.3 Metallopolymer for Detection of CO, CO_2, and NO Gas

Depending on the electrolytic interaction between the metal centers and the polymer strand and the high affinity of the metal centers for binding target ligands, they are exceptionally well-suited for the detection of small molecules such as NO and CO. In their study, Holliday et al. [31] focused on developing a gas-phase detection system for NO, CO, and CO_2 that offers selectivity at the parts-per-million level. This system relies on chemoresistive changes in a metallopolymer film device containing cobalt. To create these films, metallopolymer was synthesized and deposited onto arrays of commercially available interdigitated microelectrodes for gas-phase analysis. These electrodes consist of 50 pairs of interdigitated electrode lines spaced approximately 15 μm apart. These high-surface-area films were then easily loaded with the prepared metallopolymer through electro-polymerization, allowing for direct gas-phase testing within the electrode gaps.

6.4 Metallopolymer for Detection of HCl Gas

Kaneko et al. [70] propose a color-tunable substance in the form of an insulated metallopolymer that responds to an acidic stimulus, leading to conversion from phosphorescence to fluorescence between complementary colors. The entangled polymeric substrate of a Pt-based fluorescent metallopolymer, protected by cyclodextrin, undergoes depolymerization when exposed to HCl due to the acidic dissociation of Pt-acetylide bonds. This process results in the formation of a fluorescent monomer. The thick film of the as-prepared metallopolymer can undergo a phosphorescence-to-fluorescence transition thanks to π–π* transitions. By enhancing the interaction between the synthesized metallopolymer and hydrochloric acid vapors when exposed to UV irradiation, rapid color changes are achieved. These methods are believed to open up new avenues for the development of molecularly accurate printed sensors and next-generation color tunable materials. Additionally, π–π* transitions lead to significant energy differences and, consequently, a remarkable shift in emission wavelength [71].

Table 3 Metallopolymers and their selective study for particular gas detection

Serial number	Year/Reference	Author	Metallopolymer used	Gas detected
1	2006/[31]	Holliday et al.	Co@Poly-EDOT	CO, CO_2, NO_2
2	2012/[65]	Singh et al.	Co@PAAM	LPG
3	2016/[28]	Naidji et al.	Ru@terpyridine	Ammonia
4	2016/[67]	Luo et al.	Au@hydroxypaptite	Ammonia
5	2018/[72]	Pereira et al.	Co(salen) metallopolymer	Molecular oxygen
6	2019/[70]	Kaneko et al.	Pt@phosphorescent metallopolymer	HCl

6.5 Metallopolymer for Molecular Oxygen

Monitoring the movement within biotechnology firms, laboratories, and industries involved in the cultivation of microorganisms often requires the measurement of molecular oxygen. Pereira et al. [72] have developed a sensor platform using a chemical resistor material to create a resistance-based apparatus for detecting dispersed molecular oxygen in fluids. In their research, they electrodeposited a cobalt-selen metallopolymer thin film onto a platinum electrode to establish the chemiresistive circuit element. The sensor's resistance and capacitance characteristics are dependent on the quantity and presence of dissolved oxygen. Metal(salen) complexes undergo electropolymerization to produce π-conjugated metallopolymers with intriguing morphological properties [73]. These poly@metalsalen materials exhibit high stiffness, thermodynamic stability, and catalytic performance when interacting with various organic and inorganic compounds. Coordinating complexes often assemble into molecular nanocolumns when a metallopolymer thin film is deposited onto the surface of a conductive substrate. The sensor developed in this experiment can serve as an alternative for detecting dissolved oxygen in atmospheric samples. Electrochemical impedance spectroscopy was employed on a platinum electrode to measure the impedance of metallo-polymer films. Notably, the film conductivity of the chemiresistor sensor fluctuates in response to changes in dissolved oxygen levels, attributed to significant redox reactions. Table 3 provides examples of metallopolymers and their selective application in the investigation of specific gases.

7 Conclusion

The primary objective of this chapter is to provide an in-depth study of synthesis routes, properties, and characteristics of metallopolymers-based hazardous gas sensors. The motivation for conducting such an intensive study on metallopolymer-based hybrid matrices stems from the unique architecture and novel physicochemical properties of the material, which result from the composition of organic and

inorganic systems. Consequently, significant attention has been dedicated to understanding the characteristics, classification, and stabilization of metal incorporation into the hybrid polymer structure. Furthermore, efforts have been made to describe various types of hazardous gases, their impact on living organisms, and the respective gas sensor configurations. In prospect, these materials will find applications in biomaterials, designated drug delivery systems, quality innovation, electronics, and more. Metallopolymers have extensive applications in various fields, including supercapacitors, LEDs, solar cells, and so on. Additionally, metallopolymers-based sensors are known for their precision and accuracy, making it reasonable to assert that our future will witness significant advancements in technologies based on these materials. We have endeavored to present a comprehensive review of current techniques for hybrid metallopolymers, continuous investigation of their properties, and the broad range of their potential applications in the field of gas sensing. Although this process is still under development, it is relatively straightforward and practical to produce metallopolymers by thermally transforming metal-containing precursors incorporated into a polymer matrix through various methods. Without a doubt, these materials will continue to be used and developed in the future.

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Optical Sensors Based on Metal–Organic Frameworks

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Abstract For applications like surface-enhanced Raman spectroscopy (SERS) and luminescence, metal–organic framework (MOF) optical fiber has received a lot of attention. For the planned logical applications, any part of the MOF assembly, counting the metal hubs, natural linkers, and visitor particles, can be utilized as

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a source to make single- or multi-outflow signals. MOFs have developed into an intriguing category of materials in the field of porous materials. The distinct characteristics of these materials are the result of the combination of the properties of organic struts and metal ions/clusters, which are the building blocks of these fascinating designs. MOFs have demonstrated tremendous potential as a variety of species' sensing materials and for numerous other applications. In response to a particular analyte, the signal transduction-induced process in these minuscule, closed nanogaps generates optical output, which may be monitored in several ways. Optical fiber sensors (OFS) based on MOFs have received a lot of attention over the last three decades due to their vast range of monitoring applications in numerous industries, including aerospace, defense, security, civil engineering, and energy. The OS's primary restrictions are as follows: crass sensitivity, massive volume, and large data generation. These difficulties can be overcome by developing advanced data analytics engines powered by recent advances in machine learning (ML) and artificial intelligence (AI). This chapter provides an overview of the evaluation of recent studies of optical fiber sensors as well as the advancements in MOF-based optical detecting of ML and AI technology.

Keywords MOF · Optical sensor · AI and ML optical fiber sensor

1 Introduction

Metal–organic frameworks (MOFs), a new category of sensing ingredients, have emerged in the regime of porous materials [1]. Because of characteristics like their large surface area, structural tunability of the pore metrics, functional nano-spaces, etc., constructed from a variety of metal ion/clusters and sensitive organic ligands, these materials perform better than contemporary alternatives [2]. These permeable plans' repression impact represents an assortment of host-visitor connections with the approaching analytes and gets proper reactions, this can be accomplished with a variety of methods, including atomic emission spectrometry, electrochemical methods, and others [3]. Due to this, many approaches, such as mass spectrometry, inductively coupled plasma mass spectrometry (ICP-MS), electrochemical methods, nuclear ingestion spectrometry, and nuclear emanation spectrometry, as well as others or methods like their high surface area, can be used to accomplish this [4–6]. As fluorometric probes for identifying environmental-relevant organisms, the scientific community has paid close attention to MOFs over time [7]. Additionally, MOFs have demonstrated remarkable ability to detect substances that are harmful to the environment and toxic, making them an emerging possibility for reducing environmental pollution and associated diseases.

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This is because of a few things that control MOFs' sensing mechanisms. Luminescent MOFs (LMOFs) have attracted interest due to their improved guest identification abilities and resulting analyte-specific optical response. Reports on selective analyte detection and turn-on responsive behavior are extremely rare for MOF-based sensors, which typically rely primarily on luminescence quenching mechanisms [8–11]. Inorganic metal particles or group hubs and linkers that include natural ligands and metal–organic structures are used to create a type of permeable hybrid material known as a metal–organic framework (MOF) [12–14]. The high specific surface area, ultrahigh porosity, tunable internal surface property, extremely diverse structure, and acceptable biocompatibility are just a few of the characteristics that set it apart. MOFs are frequently utilized in purification and storage [15], catalysis [16] medication delivery, biomedicine, and chemical sensors and biosensors [17–19]. Because their emission centers can be constructed using "multiple photonic units" derived from inorganic metal ions or cluster nodes, linkers, etc., MOFs are appealing optical sensing materials or its combination to combine inorganic and organic chemistry to demonstrate structural diversity aspects [19–21]. Due to this unique property and adjustable functional sites, MOFs have highly customizable and diverse luminescence that can be used for tailored applications. With rational design, the "multiple optical units" can be manufactured or modified to provide the various luminescence signals previously described. The recent smart appliances comprised in the form of fiber optical sensor, hardware and artificial intelligence (AI) is the most recent digital revolution. Industrial infrastructure is increasingly relying on smart sensors to support intelligent operations including automated asset monitoring, problem detection, and preventive maintenance. The most popular technique for doing this is the evanescent field approach, in which the optical fiber is altered to permit the contained optical modes' evanescent tails to pass through to the outside world [22]. All of which can be used in applications that require specialized capabilities; however, in addition to connecting identification objects for communication with a specific target, The utilization of the functional sites may also be employed to increase contact with emission centers, which can change luminescence characteristics even further. Furthermore, luminous molecules from guests can be encased within the porous structure thanks to its extremely high porosity and adjustable interior surface characteristics.

To give MOFs radiometric, multiplexing strategy, and multi-methodology estimating capacities, one extra component of iridescence might be presented [23–26]. MOFs can be used as signal amplification surfaces or to construct composite substrates by enclosing metallic nanomaterials, both of which are promising materials for SERS approaches. In addition to luminescence, MOFs can also be a promising material. In addition, the large surface area and controlled pore size provide a high capacity intended for adsorbing and intent substances, resulting in a unique sieve effect and a low limit of detection (LOD), both of which enhance selection [25–28].

In general, limiting non-radiative relaxations in MOFs by including stiff functional groups, producing exciplexes or excimers with guest molecules, and so on can elicit a turn-on response. As a result, the current focus of research is on developing suitable sensors that can use LMOFs to elicit a turn-on response. The purpose of this chapter is to present optical nanosensors based on MOFs, with an emphasis on their application

in luminescence detection [29–31]. The final topic of discussion is the development of MOF-based nano-sensors for diagnostic and bioanalytical purposes.

2 Advantages of Optical Fiber Sensors Over Conventional Sensors

The headway of FOS innovation innovative work has extended their pertinence to various areas of innovation, including the clinical, compound, and telecom areas. Temperature, chemical changes, electric and magnetic fields, vibrations, strain, movement (position), flow pressure, rotation, radiation liquid level, light intensity, and color are just a few of the physical characteristics they were designed to work with. For extreme climate perseverance, FOS sensors beat conventional electric and electronic sensors concerning unwavering quality and unbending nature. Fiber optic sensors, otherwise called optical fiber sensors, utilize optical fiber as a detecting component. Temperature, pressure, vibrations, displacements, rotations, and substance concentrations can all be determined using these sensors [32, 33]. Strands have a few applications in remote detection since they require no electrical power in the far area and are small in size. In sensitive conditions like noise, high vibration, excessive heat, dampness, and uncertain surroundings, fiber optic sensors excel. These sensors can be precisely placed wherever flexible fibers are required and are small enough to fit in tight spaces. The wavelength shift can be calculated using optical frequency-domain reflectometry. The time delay of fiber optic sensors can be determined using a device with an optical time-domain reflectometer. Figure 1 demonstrates the block diagram of optical fiber sensing and Table 1 various sensing techniques and characteristics of materials are mentioned.

The measurement of physical characteristics like temperature, velocity, displacement, and strain in structures of any size or shape is just one example of the many applications for fiber optic sensors. Night vision cameras, electronic security systems, partial discharge detection, vehicle wheel loads, heritage structures, and bridges and buildings are all monitored in real time.

3 Fiber Optic Sensor Principle

In the early 1960s, fiber optic systems (FOS) for light transmission were created, which bring revolution in transmission era. Current advancements in FOS technology provide qualitative as well as quantitative benefits for continuous surveillance, vast distance measurements as well as prompt identification of threats related to infrastructure deprivation to avoid any type of losses. For real-time detection, measurement and prolonged evaluation, fiber optic-oriented observing and monitoring systems use smoothly dispersed sensing approaches [55]. This makes them enable for early smash

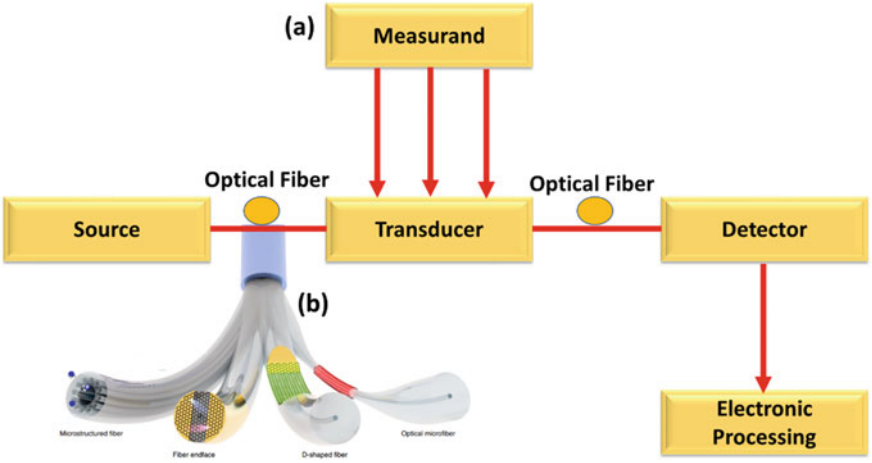

Fig. 1 **a** Block diagram of optical fiber sensing and **b** schematic MOFs of Optical fiber [34]. Open Access (2021) Nature

Table 1 Literature survey of various sensing characteristics

Optical material	Temp. (°C)	Response	Response/recovery time	References
SnO_2-Pt	200	89	20/27 s	[35]
ZnO-PANI	36	13	3.3/9.8 min	[36]
TiO_2/PANI	273	0.63	3.3/3.0 min	[37]
TiO_2/Ni	250	37	–/–	[38]
ZnO/PEDOT: PSS	27	0.58	3.7/3.1 min	[39]
ZnO/MWCNT	30	61	5.8/3 min	[40]
h-BN/-	RT	6.17	55/40 s	[41]
PANI/-	RT	12.10	11/07 s	[42]
ZnO-TiO_2/PANI	30	412	35/54 s	[43]
CdS/-	70	173	5.52/3.46 min	[44]
Ag-$BaTiO_3$/CuO	250	0.28	15/10 min	[45]
CuO-$Cu_xFe_{3-x}O_4$	250	0.50	9.5/– min	[46]
CdO	250	0.01	3.33/5 min	[47]
PEDOT-BPEI	RT	0.03	–/60 min	[48]
$La_{1-x}Sr_xFeO_3$	380	0.25	11/15 min	[49]
ZnO	200	0.03	8/40 s	[50]
ZnO-La (50%)	400	0.65	90/38 s	[51]
SnO_2/PANI/Ag	30	67	1000/900 s	[52]
TiO_2/Zn	RT	2.92	120/– Sec	[53]
Fe_2O_3/ PANI	RT	229	2.35/3.8 min	[54]

up identification, corrective action, and characterization, resulting in rapid remediation. These sensors' morphology and adaptability along with topography enable them to be successfully incorporated into structures for strain monitoring, which might help provide quickly and fast caution signals linked to timely damage detection to avert catastrophic failures. Several methods including Fiber Bragg Gratings (FBG) or scattering relay sensors are developed on the standard of interferometry and reflectometry. These optical standards have been proposed to assess dispersed strains along the intact extent of a fiber [56]. Numerous gratings are placed in discrete places along the fiber as part of the quasi-distributed strain measurement technique known as FBG. It is possible to multiplex several point sensors via a single fiber in order to collect data at a variety of different locations. Additionally, different parameters such as strain and temperature can be measured by different sensors within the same fiber. Three categories of FOS have been established yet: interferometry, reflectometry, and grating-based sensors. FOS technology relay on physical fluctuations of light waves that travel through optical fibers as a result of external inputs or stimuli. These distinctions include those that are responsive to different outside signals, such as the intensity of light, bandwidth/wavelength, phase with one another, and polarization [57].

3.1 Grating-Based Sensor

The impact of grating in mainstay of optical fibers is identified using sensors based on gratings. The grating acts as a slender band filter or transmitor/reflector to modulate assortment of wavelengths also known as Bragg wavelengths, when the light passes through an optical fiber. The warp of FBG sensors by physical factors like strain or temperature affects the fluctuation of grating frequency (υ) and refractive index (μ) especially when FBG is used as a sensing device for strain and temperature monitoring [55]. $\Delta\lambda_B$ is known as shift in Bragg wavelength results from these fluctuations as shown in Fig. 2a.

3.2 Mach–Zehnder and Fabry–Perot-Based Interferometry Sensors

The Mach–Zehnder-based sensors rely on the rule that a solitary light source beam splitter collimates the effectiveness of phase transmit changes illuminated in the midst of two beams. It depends on the length of the routes and how the optical paths alter. To measure a target's changes through phase modulation, a target can be put in the pathways. The Mach–Zehnder-based sensors may be used as a tool for monitoring changes in temperature (ΔT), liquid pressure ($\Delta\rho$), and atmospheric pressure (ΔP) in confined spaces [56, 58, 59]. The Fabry–Perot (FP)-based sensors operate under the

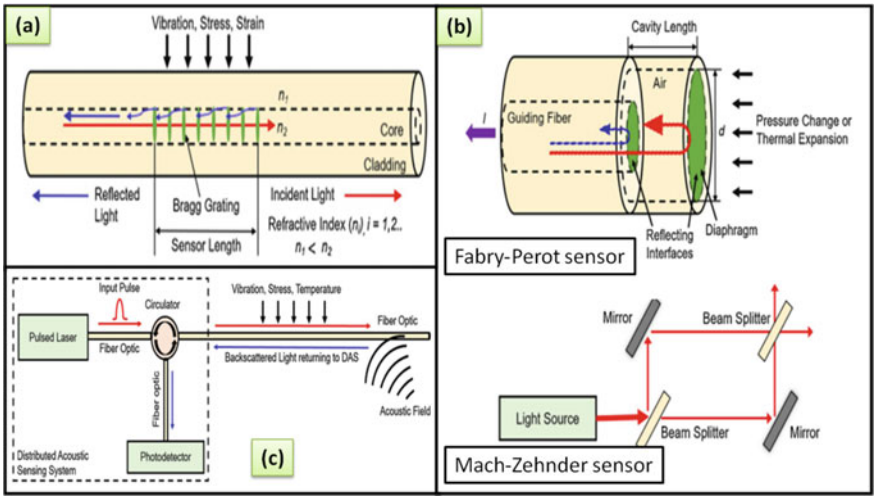

Fig. 2 **a**–**c** Schematic representation of various types of fiber optics sensor including **a** grating-based, **b** interferometry-based, and **c** scattering-based sensor [55]. Copyright (2019) Elsevier

perception, which measures the strength of interference signals that are lit between two analogous reflecting surfaces as represented in Fig. 2b.

3.3 Scattering-Based Sensor

Sensors based on scattering are excellent for long-range and continuous measurements and impart on the optical time zone reflectometry concept. When using a scattering sensing technique, an optical fiber that doubles as a sensor along its length is used to measure the backscattering of optical pulses as shown in Fig. 2c. Here backscattered signal is enhanced, modified, and altered in terms of amplitude, frequency, and phase if physical factors like temperature, strain, or vibration changes at a particular location of the fiber. It is possible to track changes in the environment by keeping an eye on the fluctuations of backscattering signals [60].

4 Detecting Mechanism of MOF-Based Sensors

Metalorganic frameworks (MOFs) are a type of extremely porous materials that are unique and provide wide range in their degree of structural variety, tunable, and broad spectrum of chemiophysical properties [61]. There are practically unlimited combinations conceivable because of the variety of metal ions and topographical structural

patterns. The exceptional ease in tuning MOF architecture and physiochemical properties is a significant advantage over other variety of sensing materials. The prospect of consistently predesigning architecture to offer desired qualities is made possible by the ability to quantitatively forecast affinities for host frameworks with superior precision. For a variety of applications such as industrialization, manufacturing operation, toxic and harmful material detection, diagnostics in radioactive sector, for secure work environments and surveillance of the environment there is elementary need of precise and receptive detection of gas and vapor elements which is provided by MOF-based sensors.

MOFs in concurrence with optical sensors provide a potentially identifiable advantage over other types of sensors. There are numerous factors that make MOFs ultrapotential candidates for sensing applications. They are proficient for offering a variety of active sites, such as open metal coordination sites and possess potential interstitial coupling between analytes and host framework either via hydrogen bonds or π–π interactions [62]. In addition to their inherent porosity, there is ease of facilitate transportation, incorporation, as well as encounters with analyte molecules. Therefore, the aforementioned locations may facilitate sensitive and swiftly interaction with the target gas molecules. Several investigations have focused on designing gas sensors using MOFs including chemiresistive sensors, impedance based sensors, luminescent and optical and gravimetric sensors [63, 64]. Optical sensors are distinguished out among these groups for their obvious benefits, including immunity to electromagnetic interferences, distant sensing abilities, user-friendly operations. During the sensing procedure, targeted molecules are frequently preferentially adsorbed. A potential strategy to adapt the pore size and orifice of MOF structure simultaneously and systematically is functionalization of organic ligands. Additionally, it influences the hydrophilic characteristics and hydrophobic nature of MOFs to give rise to the desired adhesion properties of gas molecules. Moreover, MOF defects offer a special way to adjust the adsorption properties.

The two most common lapses include omitted nodes and omitting linkers. These inconsistencies in MOFs can alter the density, as well as the stiffness, mobility, and dimension of the pores in the structure itself. Missing linker flaws in particular result in greater accessibility of metal sites, which might encourage sorption mechanisms. The subsequent sections emphasize on the MOF-oriented optical sensors, which are divided into various categories according to their sensing methods such as: colorimetric, luminescent, and optical index modulation sensing. Optical sensor usually consists of a luminosity source, a sensing element that can interfere with the molecules and detector [62, 65, 66].

MOF colorimetric sensor responses are defined as color changes, whereas fluorescent material sensors are assessed using their intensity counts. Here illumination intensity changes in response to stimulation while in case of MOF optical index-based sensors, the fluctuations in observed indices, such as the peak shift in the reflectance or transmission spectra, determine their sensitivity.

4.1 Mechanism of Chromism-Oriented MOF Sensor

The primary mechanism of MOF-based chromism sensors includes coordination configuration, transition in color, wavelength shift, and receptor-based charge transfer. When guest molecules bind to MOF made of transition metal ions, the color of the material can vary. More specifically, visitor molecule interactions in the midst of unimpregnated metal sites alter the reciprocity structure of the metal ions, influencing their electronic attributes, and ultimately provide for a prominent shift in absorption band of MOF. For instance, H_2O/NH_3 molecules cause the CO_{2+} ion's coordination number to increase from 4 to 6 and as a result, the structure of the ion changes from tetrahedral shape to octahedral shape, changing its color from dark blue to rubby red. VOC sensing may also be done using this kind of approach. Initial stage findings of chromic interactions with a d-block metal-oriented MOF after immersing it in various solvents have been reported by Dzesse et al. [67]. Furthermore, Li et al. investigated a Mn-MOF that exhibited solvatochromic activities towards ketone molecules [68]. Here, ketone molecules caused the original framework to deviate and altered the d-d transition in the visible province. Due to the M-M-to-L charge-transist from the $\pi-\pi$ orbital level to π^* orbital stage of the organic molecule [69]. For example, a crystal-to-crystal transition of a Cu-based MOF also demonstrated vapochromism shown in Fig. 3a. Given its simple results' visualization and widespread use in modern life, such as pH scales, colorimetry is one of the oldest analytical methods. A responsive core and a prompting molecule combine to produce the chromism phenomenon. The spectrum of intermolecular interactions might encompass the creation of bonds and ligand interaction as well as the weakest interactions caused by Van der Waals forces.

4.2 Mechanism of MOF-Based Magnetic Sensor

Spin crossover MOF and single molecule magnet (SMM)-MOF are the two kinds of magnetic MOFs that are utilized to create magnetic MOF-based sensing switches. These have ability to subsist in both high spin state (HSS) and low spin (LSS) states as transition metal ions have d^4–d^7 electronic configurations, which serve as the metal centroid of MOFs. The geometry, color, impedance, magnetic activity, dielectric factor, loss factor, luminous activity, and other physical properties of spin crossover MOF alter in response to peripheral corporeal and chemical stimuli, switching between two distinctive HSS and LSS zone of metal ions shown in Fig. 3b. There has been an increase in interest in SMMs made of d- and f-block metal complexes due to their potential applications in various sectors. SMM has very sensitive magnetism to external stimuli including pressure, heat, luminescence, and foreign molecules. As they can alter their spin state by changing the surrounding coordination of the core metal so reversible interchange of visiting solvent particles may affect the distances and locations between the ligands and metal ions, as well as the types of interaction

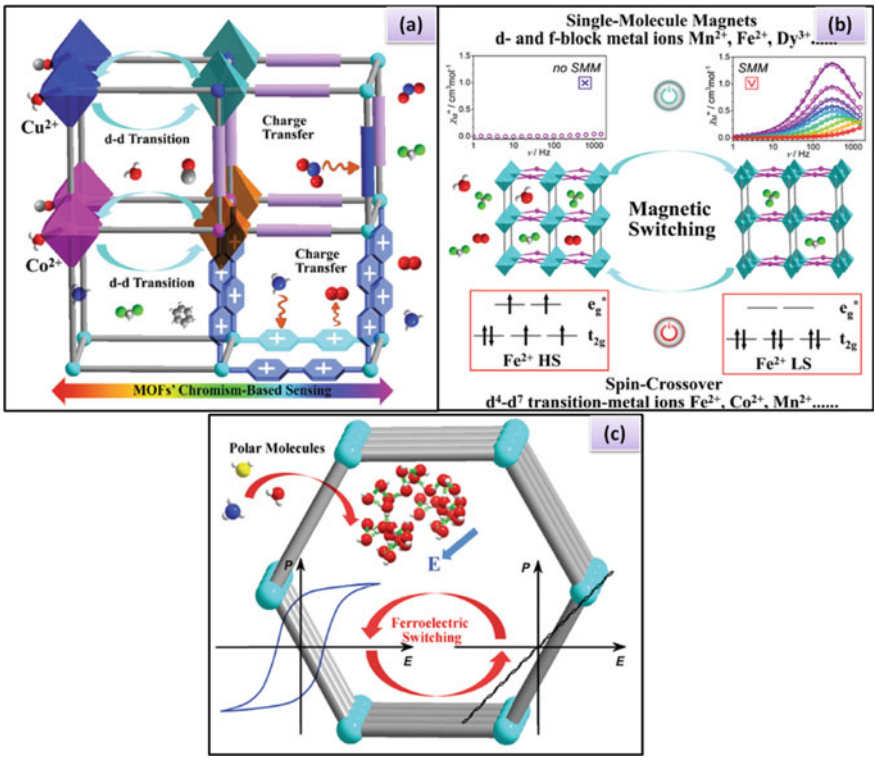

Fig. 3 Various sensing mechanisms of MOF-based gas sensor; **a** chromism **b** magnetic **c** ferroelectric mechanism [67]. Copyright (2020) Royal Society of Chemistry

of the metal center [64]. Additionally, it might result in modifications to the crystal lattice that lead to bond shaping or cleaving, which might affect magnetism.

4.3 Mechanism of Ferroelectric-Oriented MOF Sensor

The interactions between polar analyte molecules and MOFs' hydrogen bonds, which give them ferroelectric nature, are the fundamental principal source of ferroelectric mechanism in MOFs as represented in Fig. 3c. The desorption or adsorption of water molecules, together with ferroelectric toggled characteristics, is the initial stage of the SC-SC transition. The polar point networks must be constituents of the MOF space groups. The MOF should furthermore contain a hydrophilic porosity [65, 66]. The development of MOF ferroelectric switches, thus, constrained by the random nature of MOF-oriented ferroelectric switch synthesis.

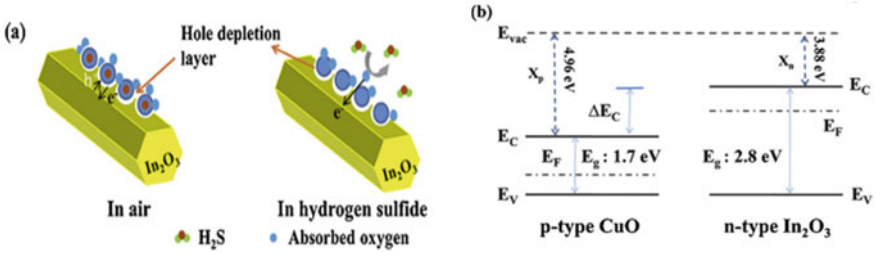

Fig. 4 **a**, **b** Schematic of carrier transportation and gas sensing mechanism for CuO/In_2O_3 sensor @ reused with permission [70]. Copyright (2020) Elsevier

4.4 Mechanism of Chemiresistive-Oriented MOF Sensor

Chemiresistive sensors are based on the elementary operating concept that is a change in the electrical characteristics (resistance, capacitance, or impedance) of the sensing material following by adsorption on contact with the gas molecule under investigation. The resistance of MOF network changes on interaction with gas analyte molecules shown in Fig. 4a, b. These electrical characteristics vary drastically on interaction [70]. The fluctuation in the sensor resistance in the existence of target gas is brought on by the Fermi energy modulation mechanism, which modifies the space charge area at the grain boundaries of thin film and gas molecules.

The electrical properties of MOFs are altered by the redox interaction between gas molecules and host metal sites of tropical organic groups. Moreover, the structural modifications by the chemisorption of gas molecules impact the conductivity of MOFs.

The sensor response [71] can be measured by:

$$S\% = \frac{(R_a - R_g)}{R_a} \times 100 \tag{1}$$

where R_a signifies the resistance in existent of air while R_g refers to resistance in the presence of gas molecule.

4.5 Mechanism of Luminescence-Based MOF Sensor

Significant and one of the most potential subsets of MOFs called luminescent metal–organic frameworks (LMOFs) have a variety of prospective uses in physiochemical monitoring, illumination, electromagnetic optical communications, and biological implant devices. Organic ligands produce luminescence phenomenon in MOF-based sensor. Typically, this class of ligand has sheer π-conjugation network. Organic compounds can glow in one of two main ways: fluorescence or phosphorescence.

The molecular fluorescence has a brief excited state lifetime and belongs to spin permissible transition, which vary from Ist singlet state (S_1) to its ground singlet state (S_0) while the swapping from the spin-forbidden triplet state to the spin-free state, which is the basis for phosphorescence, has excited state durations of 1 μs. There are numerous interactions between gas analytes and the host structure, including Van der Waals interactions and π–π interactions, etc. [61, 69]. Except these fundamental forces, inherent porosity enhances adsorption of analyte. The transition from Q-transit excited domain to ground level, including ligand-to-ligand, metal to ligand, metal to metal and ligand to metal charge impose, provides the basis for charge transfer luminescence. The foundation of these sensors was solid phase impregnation with reagents to accumulate and deliberate the analyte and exhibit color changes in reaction to the analyte for detection.

5 Intensity-Based Fiber Optic Sensor

Intensity-based fiber optic sensors can easily and more affordably replace other fiber optic sensors. Due to its simplicity, possible low cost, low weight, compact dimensions, and electromagnetic invulnerability, these intensity-based fiber optic sensors have significant importance. The theory of total internal reflection serves as the foundation for type of intensity-based fiber-optic sensors [72]. Through the fiber core, light passes before striking the angled end. Nearly all of the light that meets a mirror surface and a medium having a low appropriate index of refraction is reflected and returns through the fiber [73]. An intensity modulation results from some of the light escaping the optical fiber and being lost as the medium's index of refraction approaches that of glass. On striking the core-clad contact at angles greater than its critical angle, incident light totally reflected back and steered in the fiber while the incident light that strikes the interface at miniature angles is contorted into cladding and lost [56, 59]. A light source, an optical interface, a single or more optical fibers, an optical modulator system, detector along with signal processing components are needed as shown in Fig. 5.

However, when a fiber bends there could be losses as a result of the microlending. As a result, the output light amplitude is proportional to the degree of micro-bending. So that the sensor can be used correctly, the micro bending must be identified by detecting variations in emitted light intensity [74, 75].

6 Optical Sensor Types

Optical sensing technology is an interdisciplinary field that combines optical sensors and information science. An optical sensor is a detecting tool that transforms difficult-to-detect information straight into optical information that is simple to spot. It is frequently utilized in both daily living and engineering fields. It has numerous built-in

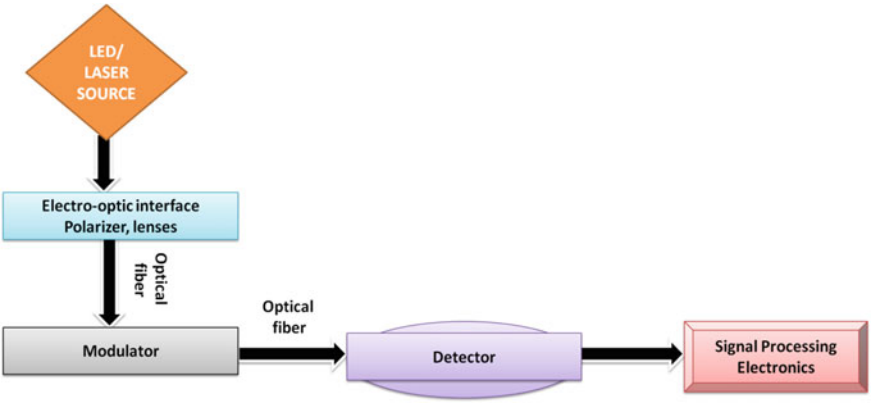

Fig. 5 Schematic block diagram of fiber optical sensor

benefits, including its lightweight, compact size, electromagnetic interference resistance, high sensitivity, reliable operation, chemical inertness, appropriate for remote sensing, protection against electromagnetic interference, and capable to monitor a wide range of chemical and physical parameters with a wide dynamic range.

6.1 Direct Sensors

The medium under vision determines how the illumination is modulated, and the composed light results from direct backscattering from the medium under investigation or medium fluorescence caused by an optical source (e.g., light-based sensors).

6.2 Indirect Sensors

Use an intermediary in response to an interested medium under test property (such as temperature or the presence of an enzyme). Additionally, indirect sensors are frequently grouped into two basic categories based on how the optical fiber is used. If the modulation happens inside the fiber itself, the sensor is said to be intrinsic. Otherwise, it is said to be extrinsic [76, 77].

6.3 Classification of an Optical Sensor

- Distributed sensor
- Extrinsic sensor
- Point sensor
- Intrinsic sensor
- Thru-beam sensor

7 Optical Fiber Sensing Application

Fiber optic sensors (FOS) have attracted much interest for their broad monitoring applications in various manufacturing, consisting of aerospace, defense, security, civil engineering, safety, and energy. Fiber optics sensor (FOS) technology has enormous potential to serve as the foundation of the coming generation of smart sensing systems that provide distributed, long-range, high-accuracy sensing capability for monitoring using several parameters and measurements with resistance to extreme environmental conditions. The primary drawbacks of FOS are (1) cross-sensitivity, (2) massive data creation and volume, (3) slow data processing, (4) the total cost of the sensor and interrogator systems, and (5) a decrease in signal-to-noise ratio across fiber length. These difficulties can be solved by developing robust analytics of data engines made possible by current advancements in machine learning (ML) and artificial intelligence (AI) [78]. Intelligent sensors are everywhere and have many uses, from voice-activated home appliances (such as Alexa, Google Home, etc.)) to the "Industrial Internet of Things (IIoT)." Miniaturization of sensing gear, cheap cloud, high-performance computing access, ample data storage, and analytics technologies. The most current developments in AI and machine learning technologies have all contributed to this revolution. Developing Deep learning research and development (R&D), a branch of machine learning (ML) that uses neural networks with biological inspiration to carry out learning tasks, has been responsible for the advancement of AI since 2012 and its important developments [79]. Machine learning techniques rely on the unique selection and extraction of particular features, while deep neural networks, like CNN, automatically extract the features [80]. DL-based artificial intelligence technologies are gradually showing better performance equivalent to humans in many real-world tasks like image recognition, speech recognition, machine translation, and personalized recommendation [81]. Applications of DL are used in chatbots, healthcare, virtual assistants, and entertainment. Figure 6 displays the possible uses of FOS combined with ML and AI technology.

FOS R&D has advanced significantly over the past two decades and compared to electrical and free space sensors, the technology now offers significant advantages in engineering. Since then, FBG sensors have been widely made after being developed for several real-world applications, including structural health monitoring (SHM, gas, oil, and gas) chemical, biomedical engineering, and ML techniques to

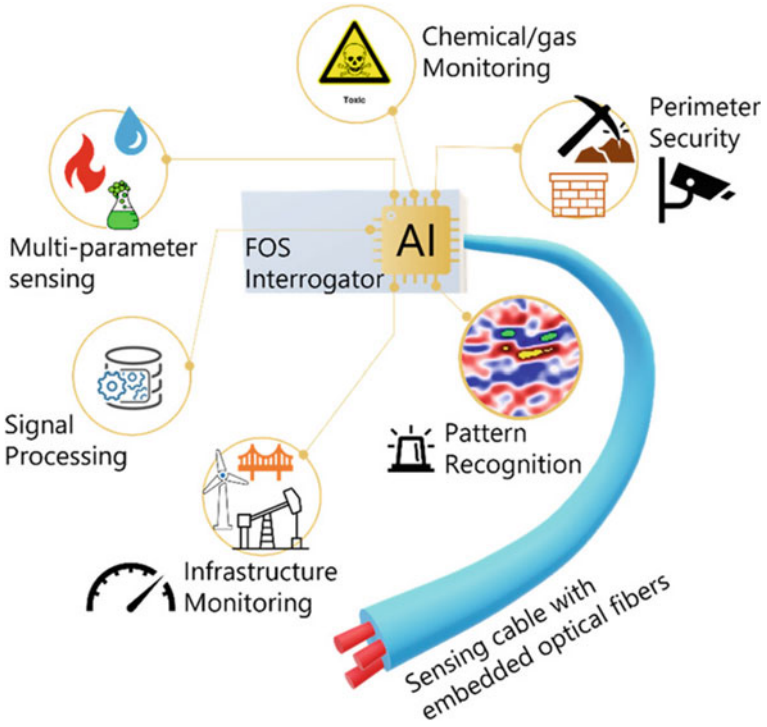

Fig. 6 AI-enhanced FOS and sensing cables with embedded optical fibers and interrogators attached are shown in a schematic for various applications [78]. Open Access (2022) Wiley Online Library

recognize patterns and regularities in data automatically. Additionally, discrete one-mode, multimode single-mode fiber-based sensors provide increased sensitivity and selectivity.

Figure 7 shows the organizational structure and depicts how the tasks involved in developing AI-enabled FOS innovations are interconnected. The several sensors, working theories, and data modalities are described in Sect. 2. In Sect. 3 examines that the difficulties and restrictions of these sensors and the opportunity this creates for the development of ML. Here, emphasize the most current developments in ML and AI that could be helpful to overcome these problems.

Some recent successes in addressing the difficulties associated with analytics of FOS data and event/pattern recognition categorization are highlighted in Sects. 4 and 5. The recent developments in Machine Learning and AI for applications in Fiber Optic Sensors.

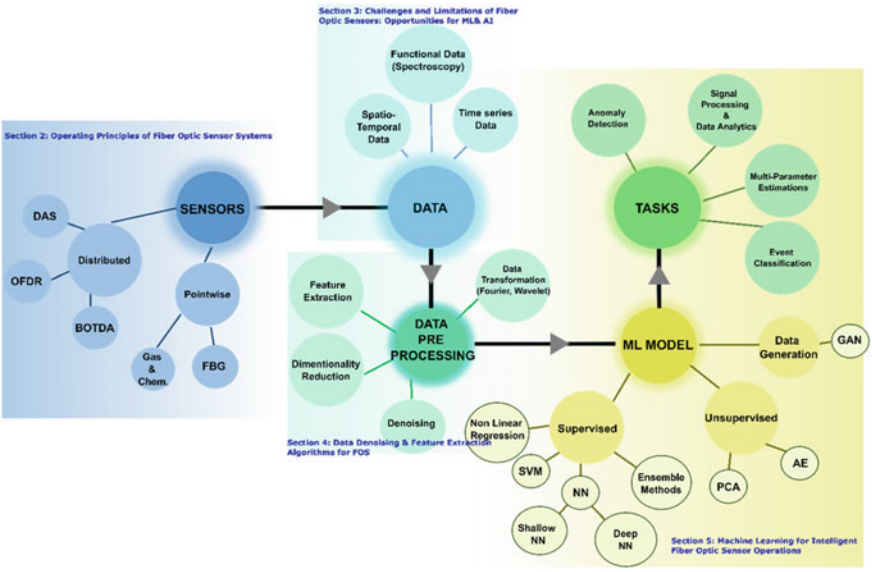

Fig. 7 Shows a hierarchy of the tasks involved in creating intelligent FOS operations [78]. Open Access (2022) Wiley Online Library

7.1 Medical Field

Numerous studies are being conducted worldwide on optical-chemical and biochemical sensing, and these sensors are being used increasingly in industry, biomedicine, environmental monitoring, medicine, and chemical analysis [82]. Because of several factors, optical biosensors are being used more frequently in various areas of medicine. Optical fiber sensors can be inserted into or inside the human body to assess biomedical parameters. Also, many fast-emerging applications utilize FOS for biomedical purposes [83]. For example,

- Oximetry and blood pressure checking
- Monitoring of gastric CO_2
- Monitoring temperature and strain using fiber Bragg gratings
- Monitoring of pressure

Modern medicine has significant problems with effective disease diagnosis and treatment, both depending on the ability and timeliness of detection. Ineffective, unreliable, and expensive detection and real-time monitoring make rapid diagnosis and treatment more expensive**.** Figure 8 shows the most recent developments in intelligent materials for creating versatile wearable sensors that provide information on their properties, uses, and applications in healthcare. The most recent generation of wearables with AI capabilities for accurate diagnosis, early detection, and making complete and customized clinical decisions [84].

About the Chief Editor

Prof. Ram Mehar began his teaching career in 2002 as contract basis Lecturer in Education in Department of Education, University School of Open Learning Punjab University Chandigarh. He also served in Haryana Civil Services (HCS) officer for a short span but resigned in 2005. Presently, he is working as Professor in Education, Department of Education University School of Open Learning Punjab University Chandigarh. With experience of over 18 years in teaching at Under Graduate and Post Graduate level, he is a keen researcher and academician. Till date, 16 students have successfully completed their Ph.D. in Education, 5 students are still working and more than 107 students did M.Ed. Dissertation under his supervision. His areas of expertise are Educational Research and Statistics, Educational Technology, Techniques of Teaching, Pedagogy of Hindi.

He has published 135 Research Papers in National and International journals of repute. Additionally, he has contributed around 60 articles/chapters in various edited books and Conference Proceedings and also presented 37 papers in International Seminars/Conferences, 115 in National Seminars/Conferences and 6 in Local/Regional Seminars/Conferences. He was also attended 42 Workshops, 35 Online Webinar during Pandemic period and also 23 seminar/conference was organized in different department of Panjab University Chandigarh. Along with this, he has delivered 82+ invited talks in various seminars, workshops organized by higher educational institutes and universities in the states of Punjab, Haryana, Himachal Pradesh and Uttar Pradesh. He has edited a book titled 'Changing Contours of Open and Distance Learning in Higher Education', 'Knowledge Technology and Higher Education' and National Education Policy 2020: A Vision for New Horizon. To his credit there is one Research Tool i.e. 'Students Engagement in Mathematics' published by National Psychological Corporation, Agra. He was a member of Advisory Committee and Editorial Board of various reputed Journals.

He was honoured with "Pariyavarn Chetna Samman" in 2012 by Samaj Dharam Mehtpur, District Una (Himachal Pradesh). He is associated with Government of Punjab as a member of State Research Advisory Committee. He acted as an Expert for Evaluation Action Research Report SSA Authority and Jury Member for State Teacher Awards in 2018. He was Chancellor's Nominee in Academic Council of Himachal Pradesh University. He was Coordinator of Ph. D. and B. Ed. Entrance Exam in 2022. He was member of Postgraduate Board of Studies in Centre for the study of Social Exclusion and Inclusive Policy, Panjab University Chandigarh and member of Research Degree Committee (RDC) in Department of Education, Sanskrit, Guru Nanak Sikh Studies, Indian Theatre, Community Education & Disability Studies, Psychology and Police Administration, Panjab University Chandigarh. He was Visiting Team Member of Inspection Committee for Grant of Approval of B. Ed., M. Ed. and DL. Ed. of National Council of Teacher Education.

In addition to contributing towards Panjab University Chandigarh, he is actively involved with various academic activities of other Universities also like Jammu University, Jammu, Kurukshetra University, Kurukshetra, Himachal Pradesh University, Summer Hill, Shimla, Bhagat Phool Singh Mahila Vishwavidyalaya Khanpur, Punjabi University Patiala, Maharishi Markandeshwar University Mullana, and Central University of Himachal Pradesh, Dharamsala.

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NATIONAL EDUCATION POLICY 2020: TRANSFORMING AND REFORMING EDUCATION IN INDIA

Chief Editor
Prof. (Dr.) Ram Mehar
Editors
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Chanakya

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It is pertinent to affirm that the facts, interpretations, and conclusions arrived in these articles are that of their respective authors. The Editors and the Publisher have no forbearing with them.

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PREFACE

The new National Educational Policy 2020 aims to bring about and execute a plethora of reforms across all levels of education in India, including the essential understanding of education in the country. It also seeks to implement changes in the way the facilitators of such education – schools, colleges and teachers – are trained and how they approach education. Among other things, the NEP has renamed the Ministry of Human Resource Development (MHRD) as the Ministry of Education, a sign of the country's changing focus on education. The policy is based on the pillars of "access, equity, quality, affordability, accountability" and will transform India into a "vibrant knowledge hub", tweeted Prime Minister Narendra Modi soon after it was unveiled. The book "**National Education Policy 2020: Transforming and Reforming Education in India**" provides a vehicle to understand what are the reforms the NEP 2020 aims to bring about and how does it seek to change the landscape of Indian learning? Since it is an emerging area, the best way to capture the current research activity and to set the perspectives and challenges in this field is by inviting and selecting high-quality work from researchers, academicians, teachers, professors and vice-chancellors in the form of chapters of a book. These chapters will be authored by leading experts offering an in-depth description of key terms and concepts related to role of National Education Policy, 2020 in Transforming and Reforming Education in India.

Education is fundamental for achieving full human potential, developing an equitable and just society, and promoting national development. Providing universal access to quality education is the key to India's continued ascent, and leadership on the global stage in terms of economic growth, social justice and equality, scientific advancement, national integration, and cultural preservation. Universal high-quality education is the best way forward for developing and maximizing our country's rich talents and resources for the good of the individual, the society, the country, and the world. India will have the highest population of young people in the world over the next decade, and ability to provide high-quality educational opportunities to them will determine the future of our country.

The global education development agenda reflected in the Goal 4 (SDG4) of the 2030 Agenda for Sustainable Development, adopted by India in 2015 - seeks to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" by 2030. Such a lofty goal will require the entire education system to be reconfigured to support and foster learning, so that all of the critical targets and goals (SDGs) of the 2030 Agenda for Sustainable Development can be achieved. The world is undergoing rapid changes in the knowledge landscape. With various dramatic scientific and technological advances, such as the rise of big data, machine learning, and artificial intelligence, many unskilled jobs worldwide may be taken over by machines, while the need for a skilled workforce, particularly involving mathematics, computer science, and data science, in conjunction with multidisciplinary abilities across the sciences, social sciences, and humanities, will be increasingly in greater demand. With climate change, increasing pollution, and depleting natural resources, there will be a sizeable shift in how we meet the world's energy, water, food, and sanitation needs, again resulting in the need

for new skilled labour, particularly in biology, chemistry, physics, agriculture, climate science, and social science.

The growing emergence of epidemics and pandemics will also call for collaborative research in infectious disease management and development of vaccines and the resultant social issues heightens the need for multidisciplinary learning. There will be a growing demand for humanities and art, as India moves towards becoming a developed country as well as among the three largest economies in the world. Indeed, with the quickly changing employment landscape and global ecosystem, it is becoming increasingly critical that children not only learn, but more importantly learn how to learn. Education thus, must move towards less content, and more towards learning about how to think critically and solve problems, how to be creative and multidisciplinary, and how to innovate, adapt, and absorb new material in novel and changing fields. Pedagogy must evolve to make education more experiential, holistic, integrated, inquiry-driven, discovery-oriented, learner-centred, discussion-based, flexible, and, of course, enjoyable. The curriculum must include basic arts, crafts, humanities, games, sports and fitness, languages, literature, culture, and values, in addition to science and mathematics, to develop all aspects and capabilities of learners; and make education more well-rounded, useful, and fulfilling to the learner. Education must build character, enable learners to be ethical, rational, compassionate, and caring, while at the same time prepare them for gainful, fulfilling employment. The gap between the current state of learning outcomes and what is required must be bridged through undertaking major reforms that bring the highest quality, equity, and integrity into the system, from early childhood care and education through higher education. The aim must be for India to have an education system by 2040 that is second to none, with equitable access to the highest-quality education for all learners regardless of social or economic background.

The National Education Policy (NEP) was approved by the Union Cabinet of India on July 28th, 2020. After a gap of 34 years, the Indian government consolidated feedback from 2.5 lakh village-level stakeholders to two national parliamentary level committees, over more than 50 months of consultations and workshops. The aim of the policy is to prepare the children of India with 21st century skills. The policy is founded on the three pillars of Research, Innovation, and Quality, with the objective of developing India into a knowledge super power. Built on the foundational pillars of Access, Equity, Quality, Affordability and Accountability, this policy is aligned to the 2030 Agenda for Sustainable Development and aims to transform India into a vibrant knowledge society and global knowledge superpower by making both school and college education more holistic, flexible, multidisciplinary, suited to 21 century needs and aimed at bringing out the unique capabilities of each student.

This National Education Policy 2020 is the first education policy of the 21st century and aims to address the many growing developmental imperatives of our country. This Policy proposes the revision and revamping of all aspects of the education structure, including its regulation and governance, to create a new system that is aligned with the aspirational goals of 21st century education, including SDG4, while building upon India's traditions and value systems. The National Education Policy lays particular emphasis on the development of the creative potential of each individual. It is based on the principle that education must develop not only cognitive capacities - both the 'foundational capacities 'of literacy and numeracy and 'higher-order' cognitive capacities, such as critical thinking and problem solving – but also social, ethical, and emotional capacities and dispositions.

From School Education to Higher Education, the NEP envisions to provide a new structure to the education sector of

the country. This new policy will pave the way for transformational reforms in school and higher education in the country. New Policy aims for Universalization of education from pre-school to secondary level with 100% GER in school education by 2030. NEP 2020 will bring 2 crores out of school children back into the main stream. A new 5+3+3+4 school curriculum with 12 years of schooling and 3 years of Anganwadi/ Pre-schooling has been introduced.

There would be emphasis on foundational literacy and numeracy, no rigid separation between academic streams, extracurricular, vocational streams in schools. The vocational education will start from Class 6 with internships in the New National Education Policy 2020 (NEP-2020). Teaching up to at least Grade 5 to be in mother tongue/ regional language. Assessment reforms with 360-degree Holistic Progress Card, tracking Student Progress for achieving Learning Outcomes. GER in higher education to be raised to 50% by 2035 and 3.5 crore seats to be added in higher education.

Higher Education curriculum to have Flexibility of Subjects and multiple entry / exits to be allowed with appropriate certification. Academic Bank of Credits to be established to facilitate Transfer of Credits. National Research Foundation to be established to foster a strong research culture. Light but Tight Regulation of Higher Education, single regulator with four separate verticals for different functions.

NEP also proposes a considerable change in the examination structure. Key stage assessments (at Grades 3, 5 and 8) would be conducted to track the development of the child. As for the secondary stage, the board examinations would be reformed. They would be made easier where students would be tested on the core capabilities. Instead of just one board, a more modular model to be explored and is expected to be in place by 2022-23.

In the New National Education Policy (NEP) 2020, affiliation system to be phased out in 15 years with graded autonomy to colleges. NEP 2020 advocates increased use of technology with equity and National Educational Technology Forum to be created. NEP 2020 emphasizes setting up of Gender Inclusion Fund, Special Education Zones for disadvantaged regions and groups. New Policy promotes Multilingualism in both schools and HEs. National Institute for Pali, Persian and Prakrit, Indian Institute of Translation and Interpretation to be set up. Ministry of Human Resource Development would henceforth be referred to as the Ministry of E.

The rich heritage of ancient and eternal Indian knowledge and thought has been a guiding light for this Policy. The pursuit of knowledge (Jnan), wisdom (Pragyaa), and truth (Satya) was always considered in Indian thought and philosophy as the highest human goal. The aim of education in ancient India was not just the acquisition of knowledge as preparation for life in this world, or life beyond schooling, but for the complete realization and liberation of the self. World-class institutions of ancient India such as Takshashila, Nalanda,Vikramshila, Vallabhi, set the highest standards of multidisciplinary teaching and research and hosted scholars and students from across backgrounds and countries. The Indian education system produced great scholars such as Charaka, Susruta, Aryabhata, Varahamihira, Bhaskaracharya, Brahmagupta, Chanakya, Chakrapani Datta, Madhava, Panini, Patanjali, Nagarjuna, Gautama, Pingala, Sankardev, Maitreyi, Gargi and Thiruvalluvar, among numerous others, who made seminal contributions to world knowledge in diverse fields such as mathematics, astronomy, metallurgy, medical science and surgery, civil engineering, architecture, shipbuilding and navigation, yoga, fine arts, chess, and more. Indian culture and philosophy have had a strong influence on the world. These rich legacies to world heritage must not only be nurtured and preserved for

posterity but also researched, enhanced, and put to new uses through our education system.

The teacher is at the centre of the fundamental reforms in the education system. The new education policy must help re-establish teachers, at all levels, as the most respected and essential members of our society, because they truly shape our next generation of citizens. It must do everything to empower teachers and help them to do their job as effectively as possible. The new education policy must help recruit the very best and brightest to enter the teaching profession at all levels, by ensuring livelihood, respect, dignity, and autonomy, while also instilling in the system basic methods of quality control and accountability. The new education policy must provide to all students, irrespective of their place of residence, a quality education system, with particular focus on historically marginalized, disadvantaged, and under represented groups.

Education is a great leveler and is the best tool for achieving economic and social mobility, inclusion, and equality. Initiatives must be in place to ensure that all students from such groups, despite inherent obstacles, are provided various targeted opportunities to enter and excel in the educational system. These elements must be incorporated taking into account the local and global needs of the country, and with a respect for and deference to its rich diversity and culture. Instilling knowledge of India and its varied social, cultural, and technological needs, its inimitable artistic, language, and knowledge traditions, and its strong ethics in India's young people is considered critical for purposes of national pride, self-confidence, self-knowledge, cooperation, and integration.

The implementation of previous policies on education has focused largely on issues of access and equity. The unfinished agenda of the National Policy on Education 1986, modified in 1992 (NPE 1986/92), is appropriately dealt with in this

Policy. A major development since the last Policy of 1986/92 has been the Right of Children to Free and Compulsory Education Act 2009 which laid down legal underpinnings for achieving universal elementary education.

The purpose of the education system is to develop good human beings capable of rational thought and action, possessing compassion and empathy, courage and resilience, scientific temper and creative imagination, with sound ethical moorings and values. It aims at producing engaged, productive, and contributing citizens for building an equitable, inclusive, and plural society as envisaged by our Constitution. A good education institution is one in which every student feels welcomed and cared for, where a safe and stimulating learning environment exists, where a wide range of learning experiences are offered, and where good physical infrastructure and appropriate resources conducive to learning are available to all students. Attaining these qualities must be the goal of every educational institution. However, at the same time, there must also be seamless integration and coordination across institutions and across all stages of education.

This National Education Policy envisions an education system rooted in Indian ethos that contributes directly to transforming India, that is Bharat, sustainably into an equitable and vibrant knowledge society, by providing high-quality education to all, and thereby making India a global knowledge superpower. The Policy envisages that the curriculum and pedagogy of our institutions must develop among the students a deep sense of respect towards the Fundamental Duties and Constitutional values, bonding with one's country, and a conscious awareness of one's roles and responsibilities in a changing world. The vision of the Policy is to instil among the learners a deep-rooted pride in being Indian, not only in thought, but also in spirit, intellect, and deeds, as well as to develop knowledge, skills, values, and

dispositions that support responsible commitment to human rights, sustainable development and living, and global well-being, thereby reflecting a truly global citizen.

I would like to take this opportunity to express my heartfelt thanks for the time and effort that Prof. Harsh Gandhar, Professor of Economics, University School of Open Learning, Panjab University, Chandigarh; Prof. Supreet Kaur, Professor of Education, University School of Open Learning, Panjab University, Chandigarh, and Prof. Anuradha Sharma, Department of Community Education and Disability Studies, Panjab University, Chandigarh have put into reviewing the edited book "National Education Policy 2020: Transforming and Reforming Education in India". The critical feedback, insightful remarks, and constructive ideas made by our review committee were extremely helpful in developing the book's final edition. I truly appreciate the time and effort that you have dedicated to reviewing the book. Your thoroughness and professionalism have made a significant contribution to the quality of the final product. I am grateful for your commitment to advancing knowledge in our field and for your generosity in sharing your insights and expertise with me.

Finally, we would like to thank our readers for their continued support and interest in our publications. We hope that the preface has whetted your appetite for what promises to be an enlightening and enriching read.

Once again, thank you for your attention and support, and we look forward to your feedback and comments on the book.

Best Regards.

Editors

CONTENTS

CHAPTER-9

NATIONAL EDUCATION POLICY 2020: FROM THE POINT OF VIEW OF PRACTITIONER

Prof. Ravi Inder Singh*
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Abstract

The whole universe revolves around the human beings and their life. We all strive to provide the best quality life on this planet and education is one of those means which aims at enhancing the quality of life. The actual objective of education should be to help the individuals in their mental development, in development of their thought process, in enabling them to fly their thought process in all the directions with full freedom. Therefore, education is about freedom of mind and not conditioning of mind. Only free mind learns and freedom should be accompanied with responsibility of learning. There is a need to understand that the objective of education is to provide a better society to human beings and not to condition the human beings as per the requirement of society. India is second largest country in the world with a

home to more than 133 crore people. With more than 1000 universities and more than 45000-degree colleges, India has a very large and strong network of educational institutions in the world. But unfortunately, our standing in the world as per various rankings should be a cause of concern, as per QS World University Rankings 2022, there are only 35 institutes among the 1300 institutions ranked by it at the global level and none of Indian educational institutions could figure among the world's top 100 ranks (India Today, June 11, 2021). Similarly, as per Times World University Rankings for 2022, the best ranked Indian Institution fell in the band of 301-350. But the sigh of relief in Times World University Ranking was that the number of qualifying institutions for Times World University Ranking Increased to 71 in 2022 from 63 of last year (Economic Times, Sept. 02, 2021). Most of the top ranked institutions of higher education in QS world university ranking and Times Higher Education ranking are from United States and United Kingdom. Similarly, India is ranked at 46th Position in Innovation Index at the global level (Mint, 21st September, 2021). So far as the Human Development Index of the country is concerned, India is ranked poorly at 131th rank among 189 countries (Economic Times, 17th December, 2020). Among the various initiatives which can help the country in solving its socio-economic problems and can take the growth of the country to higher levels, is the provision of relevant best quality education in the country. In the light of above, it is aspired that the National Educational Policy 2020 shall help the education in achieving its real objective. National Education Policy 2020, in a VUCA (Volatile, Uncertain, Complex and Ambiguous) world was highly needed as over the last three decades entire world and also almost all the sectors of the Indian economy under

the changed policy stance (state-controlled economy to free market economy) of the government have seen significant change. Though after the initiation of economic reforms process in 1990-91, several changes were introduced in the education sector as well, but an overall policy document, like Education Policy, stating the vision of the policy makers for the education sector and giving direction to the education sector was missing. Therefore, whereas the Indian economy has moved through phenomenal change in the last 2 to 3 decades, Indian education system remained almost the same resulting in lower rating of the institutes of higher education at the global level. Despite many changes introduced in the education sector before the launch of National Education Policy, the main approach of Indian education has been the same as was followed during the pre-independence era. The main focus of education has always been on making Indians hard workers, and therefore the content and approach of the education system didn't boost the creativity among the learners. Therefore, there was an emergent need of rejuvenation of both school and higher education in the country.

Keywords: National Education Policy, Practitioner

Introduction

National Education Policy 2020 which should have been introduced much earlier along with the initiation of economic reform process of 1990s, has come after a long gap of 34 years to replace the education policy of 1986. The launch of National Education Policy 2020 is expected to invigorate the Indian education system and aspires to make Indian education sector as the best in the world. In this article, analysis of National Education Policy 2020 is made with a comparison to societal needs. The major changes and

underlying tone of the National Education Policy 2020 has almost all the contents which if implemented properly will help in upgrading the quality of education, build confidence in Indian youth, promote the culture of innovation, will be highly instrumental in improving the ranking of Indian educational institutions and will ultimately help in achieving the mission of getting quantum jump in the economy.

National Education Policy 2020 puts teacher and student at the center and whole provisions of policy revolve around teacher-student development. Under the Gurukul system of education in India, teachers used to be at the core of the whole learning process. However, with the passage of time, the importance of important pillar, teacher, got reduced and focus shifted on building good buildings for both the school and higher education institutions. The success or failure of any educational institution and therefore of the country is dependent on the quality of teachers it has, as teachers are actually the nation builders. People are ready to adjust for all the discomfort, sit on ground and learn also, subject to the condition that the teacher is providing them good quality relevant education. National Education Policy 2020 by highlighting the importance of teacher and placing him at the central place of entire learning process has tried to address the root cause of low-quality education in the country. National Education Policy 2020 has tried to address the issue of providing quality teachers and restore the respect of teachers through reforms in their recruitment, continuous professional development, positive working environments and service conditions. In the fast-changing world, where not only the content is changing but pedagogy is also changing fast, the regular development and training of teachers on professional lines is highly needed.

The National Education Policy 2020 has rightfully highlighted the importance of continued training of teachers

on professional lines. Yet another important aspect Holistic Development of Student has been given high importance in National Education Policy 2020 both in terms of clear-cut objective as well as in terms of underlying tone of the policy. For a long period of time both school and higher education institutions in our country were giving priority only to academic aspects and participation in sports and other extra-curricular activities were assigned secondary position, as a result the performance of India in sports despite of huge population is not that encouraging. National Education Policy 2020 has envisioned removing the wall between academic and extra-curricular activities. It stresses on the holistic development of every student in academic as well as non-academic spheres. Policy talks about sensitizing teachers as well as parents to identify and work to promote every student's holistic development in both academic and non-academic spheres. Flexible Approach in education is another good initiative introduced. Policy talks about following a flexible approach and allows the learners to choose and change their learning trajectories and programmes as per their talents and interests and as per changed requirements. In the present system of education, a student has to remain tied to the specialization area of study selected by him once for his/her entire life, which is highly inappropriate looking into the quantum and speed with which the world is changing in the present era, things relevant today, may become irrelevant tomorrow. Moreover, an individual should have the freedom to select, change and rechange the area of study he/she wants to pursue otherwise also.

The flexibility approach incorporated in NEP 2020 in terms of freedom granted to learner to shift from one course to another, option of studying different subjects from different areas of study and shifting from one educational institution to another at different stages of a study program is a welcome

step. The flexibility approach will increase the interest of the learners in education, will keep the interest alive, will help in achieving holistic development of the learner and will help in increasing the employability worth of the human resources. Flexible approach will also boost the quality of education as it promotes the spirit of competition. The multidisciplinary approach of education, as required in NEP-2020 will also help in developing the thought process of the learner and achieve the mission of holistic development of the learner.

Multidisciplinary approach eliminating the wall of division between arts and sciences, between vocational and academic streams, between curricular and extra-curricular activities etc. with the objective to provide flexibility to learner, coupled emphasis on conceptual understanding approach of the policy and rather than just doing rote learning for higher marks with the objective to achieve the aim of holistic development of the learner will change the face of entire education sector. Hitherto the policy followed in our education system was aimed at channelizing the energy and learning process of the learner in one area only, which was just like putting the flap on the eyes and mind of the learner, the way we put flap on the eyes of the horse and restrict his vision. Multidisciplinary approach will open up the mind of the learner and help in enhancing the problem solving and creative ability of the learner which is highly required to take India to higher levels of development. India's GDP is just around US$2.7 and per capita income based on PPP; the GDP was expected to be around US$ 7,333 in 2021. The world rank is 128, and the Asian rank is 31.

There is a need of quantum jump in the economy which can only be attained through inventions, therefore there is a need to build confidence among our youth and channelize all our energy and resources towards promoting the culture of innovation in the society. The underlying tone and specific

mention in the NEP to encourage logical decision-making and innovation is much needed step, as it will promote the culture of innovations in the country and help it in getting quantum jump. Policy further aims at promoting the cultural of autonomy to teacher and the academic institutions which will help the educational institution to take major decisions regarding course content design and re-design as per the requirement in an easy and quick mode without waiting for the universities to take the final call. This culture of autonomy to teacher and the academic institution will increase the efficiency of the educational institutions. Policy also highlights the importance of research and requires the establishment of National Research Foundation. NRF is the outcome of realization that quality research and innovations are keys to the economic growth of the nation.

The Government of India pronounced its commitment to promote quality interdisciplinary researches through the Budget Speech of the Finance Minister, Smt. Nirmala Sitharaman who announced the provision of National Research Foundation to strengthen research ecosystem in the country with emphasis on identified "thrust areas relevant to our national priorities and towards basic science without duplication of effort and expenditure".

National Education Policy 2020 floats a vision of promoting multidisciplinary research in the country and makes India a global hub for quality education. The establishment of National Research foundation with a focused approach of promoting quality research in public and private higher educational institutions will surely help in improving the research quality, coupled with the establishment of large multi-disciplinary educational institutions with strength of 3000 students will further help in improving the global ranking of Indian Higher Educational Institutions.

Challenges

Though the National Education Policy 2020 has all the contents starting from school education to institutes of higher education which promises improvement in quality of education and research and enlists provisions of institution and teacher autonomy but successful implementation of the policy provisions is not free of challenges. The NEP-2020 lays out a comprehensive design including pedagogical, quality, accessibility to all aspects and envisions to make the learners future ready but along with this the NEP has the most challenging task of addressing multiple crises in the education system. First and foremost, challenge is the successful implementation of NEP as India is a huge country with wide diversity in culture, approach of teaching, quality of teacher and student, to make all fit one size is actually a herculean task.

Besides the issue of coordination involved in the successful implementation of the scheme, there are other major issues such as building of infrastructure, competency building among the teachers, remove inefficiency in the system, though policy talks about autonomy to educational institutions but how to control and ensure that quality of education is maintained. Policy talks about increasing GER to 50 percent by 2035, which needs huge infrastructure in terms of classrooms, their furnishing, and also large number of qualified teachers, how all this will be done looks highly challenging. Through rigorous efforts and regular review only the mission of NEP-2020 can be realized.

Conclusion

National Education Policy 2020 is a comprehensive document laying the roadmap of futuristic education; it covers almost all the important aspects which were desired to be taken up in the education policy of the country. The

national education policy has the flair to transform India as a global destination for affordable quality education with 360-degree holistic approach to develop learners as job-provider instead of a job-seeker. The challenge associated with National Education Policy 2020 is its successful implementation as the task involved is daunting and requires coordination among the various state and center government bodies associated with education sector, continued monitoring of the implementation process may help in successful implementation of National Education Policy 2020.

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The trauma and tragedy of India's partition in 1947 were profound and far-reaching, leaving an indelible mark on the collective memory of the subcontinent. Several aspects contributed to the overwhelming sense of loss and anguish during this period, like mass violence and loss of lives, forced migration and displacement, abduction and abandonment along with property loss and economic disruption. The communities that had coexisted for centuries were suddenly divided along religious lines, leading to a loss of shared heritage and cultural practices. The agony and suffering of partition are not only evident in historical accounts but are also deeply reflected in the literature, art, and memories of the survivors and their descendants. The scars of partition continue to influence the sociopolitical landscape of both India and Pakistan, serving as a poignant reminder of the importance of peace, tolerance, and understanding to prevent such catastrophic events in the future. There are many writers from Punjab who have made significant contributions to literature in various languages. This book is an exploration of the suffering, violence, tragedy, agony and horrors of the partition. The research papers in the book touch upon various aspects, including the portrayal of historical events, character development, writing style, thematic exploration, and cultural representation.

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TRAUMA ,TERROR & AGONY OF PARTITION: A STUDY OF PUNJAB WRITERS

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Moral Courage and Fortitude in the Face of Disaster: A Study of Saadat Hasan Manto's *Mozelle*.

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Abstract

Natural phenomena like earthquakes, volcanic eruptions, landslides, avalanches, tsunamis, flash floods, etc. are an intrinsic part of the Earth's natural cycle. When they cause grievous loss to human life, livestock, infrastructure, and the environment, they are termed natural disasters. At times some of these are directly attributed to human factors like indiscriminate felling of trees, destruction of forests, blasting of mountains for widening roads, etc. Then they are termed man-made disasters. There is one more kind of disaster caused by men knowingly which causes massive upheaval in the lives of people. Large numbers of innocent, ordinary people are left bewildered, shocked, and devastated. A vast majority of them perish in the most heart-rending of ways. This saga of excruciating pain has had many chapters sprinkled liberally all over the world and continues to do so with the result that mankind has lost faith in mankind itself. However, there have been shining examples of moral courage and fortitude that have redeemed mankind from ignominy. To date, the Partition of our country is the most harrowing chapter in history. Saadat Hasan Manto's *Mozelle* depicts the violent realities of Partition, indicting the perpetrators of this colossal tragedy and celebrating the heroes who displayed exceptional courage and forbearance in saving precious lives.

Keywords: Disaster, Partition, Suffering, Challenge, Cowardice, Moral courage.

The Holocaust of the Jews by Nazi Germany where the state became the persecutor of millions of innocent people in the name of 'ethnic cleansing' is unparalleled in the annals of history. It brought to the fore brute forces lurking deep within the human psyche in the form of innovative methods of third-degree torture inflicted in the nefarious concentration camps. This cataclysmic event also propelled men of honour and integrity to save the victims from any further harm at the risk to their own lives. It has also inspired writers and filmmakers to give faithful and moving portrayals of such events. Steven Spielberg's *Schindler's List* (1994), *Life is Beautiful* (1997), and *Escape from Sobibor* (1987) are only a few examples. The two world wars saw millions of people caught up in senseless violence. Earlier, the Reign of Terror unleashed during the French Revolution in 1789 was another calamitous occurrence in the history of mankind. Baroness Orczy's novel *The Scarlet Pimpernel* (1905) recounts the story of a dare-devil English aristocrat who under disguise saved many members of the French aristocracy right from under the Guillotine and smuggled them out to safety.

Unfortunately, the dictum' history repeats itself is repeatedly and fatally proved true, time and again. Jean-Paul

Sarte alluded to this when he wrote in his Preface to Franz Fanon's *The Wretched of the Earth*: "I think we understood this truth at one time, but we have forgotten it - that no gentleness can efface the marks of violence;" (18) When the 1984 anti-Sikh riots took place, those who were the victims or witnesses of the earlier 1947 carnage stated that they had never thought even in their wildest dreams that such things could happen to them again and that too in their own country. 75 years of Independence have gone by and yet the soul of the motherland continues to be riddled with similar grievous wrongs and violations. Alok Bhalla in his edited volume, *Stories about the Partition of India*, says:

> ...the religious prophets never killed,...the Sufis were men of peace and tolerance,... the ecstatic songs of Kabir and Mirabai should be sung once again to remind us all of the fact that the grace and delight of Life are a part of our real heritage. (Introduction vii)

Urvashi Butalia in her book, *The Other Side of Silence* also says: "The political partition of India caused one of the greatest human convulsions of history." (3) More than ten million people crossed the border on either side of the fateful Radcliffe line. Human columns called 'kafilas' which stretched for many dozens of miles are reported to have walked across the border in both directions. Sometimes, it took as many as eight days for the entire 'kafila' to pass from a particular place on its route. Many people were slaughtered and many died from malnutrition and contagious diseases.

> ...somewhere around a million people died...about 75,000 women are thought to have been abducted and raped by men of religions different from their own (and indeed sometimes by men of their own religion). Thousands of families were divided, homes were destroyed, crops left to rot, villages abandoned. (Butalia)

The newly formed governments of India and Pakistan were unprepared to handle the catastrophe. Climatic conditions further aggravated the human tragedy:

> In September, the elements lent a hand: unusually heavy rain led to floods and disrupted the lines of communication. Rail traffic had to be slowed down, it became difficult to travel by road, and in the kafilas, the rain led to illness and disease. (Butalia 77)

The Partition of the country disrupted the lives of millions of people and brought to an abrupt end the life of interdependence that the communities had been leading. All of a sudden, the rich fabric of their shared customs and practices was brutally ripped apart and they were left utterly bewildered and lost. The communal riots of 1947- 48 are so deeply engraved on the psyche of the nation that the memories of the same singe the soul every time they are recalled or retold. In the name of pseudo-religiousness, sheer madness was let loose. Yasmeen Khan writes: "Ultimately, during the Partition that ensued, Indians turned against each other..." (63)

> By the end of the first week of March, within days of the collapse of the ministry, quarters of most of the major cities in Punjab were burning: Lahore, Amritsar,

Jullundur, Rawalpindi, Multan, and Sialkot all had sections gutted. Gangs roamed the streets, some wearing steel or tin helmets, setting shops and houses on fire (the government quickly restricted the sale of diesel and petrol), firing weapons and throwing heavy rocks and glass soda bottles.' (Khan 118)

Erstwhile neighbours turned into murderers, looters, rapists, and tormentors. As Jean-Paul Sarte wrote "...the torrent of violence sweeps away all barriers;" (Fanon 17) The irrational passions of people exploded into an orgy of phantasmagoric bloodlust. It severed the ties between the two communities forever and sowed the seeds of hatred and suspicion so deep that we have seen a repetitive relapse of this violent frenzy by vested interests again and again over the years. Many writers tried to make sense of this surge of hatred. These stories are appalling and arouse our disgust, dismay, rage, and sense of helplessness. Amidst stories of mutilations of women, massacres, and properties burnt and vandalized, some stories record acts of kindness and decency; courage and selflessness that succeeded in saving precious lives. Saadat Hasan Manto (1912-1955) was a writer whose short stories etched, in indelible ink, the horrors of Partition with raw honesty. His graphic details exposed the sordidness of the collective soul of humanity that surrendered itself to bestiality in the most shameful chapter of the country's history. He was one of those few writers who dared to write and publish his work at a time when most writers had either laid down their pens in fear of the consequences of speaking out or due to lack of sufficient literary prowess to give adequate

expression to the senseless savagery. Manto was neither afraid nor lacking in literary talent. If anything, he was a true literary giant for bringing to life the naked emotions of grief, shock, despair, pain, fear, and frenzy in the compact form of the short story, a genre that has been mastered by only the greatest of the writers the world over. His short story, *Mozelle* upholds his message of humanism. First published in 1951 in *The Hindu Times* in Urdu, it has been subsequently translated intomany languages. It deals with the relationship between a Jewish woman and a Sikh man in Bombay during the riots. Mozelle is described as a gutsy woman who knew what power her voluptuous beauty had over men. Manto portrays her as a promiscuous woman who abhorred traditional values. A Sikh man, Tarlochan Singh falls in love with her but she rejects him because she does not find him manly enough. She tells him,"....you are a silly coward and I need a fearless man." (web) However, Tarlochan persists, and she agrees to marry him on one condition. He would have to cut off his unshorn hair and beard. He complies the very next day but Mozelle does not show up at the appointed hour. Tarlochan feels betrayed and vows to forget her and grow back his hair and beard. Very soon he falls in love with a conservative Sikh girl, Kirpal Kaur. In the meanwhile, the Partition riots have broken out in Bombay. Tarlochan is scared about the safety of Kirpal Kaur who lives in a Muslim-dominated locality. At this juncture, Mozelle returns. Her innate humanity makes Tarlochan confide in her about his fears regarding Kirpal Kaur's safety because her residence was in a muslim majority locality.

Depressing features of Partition in other parts of the subcontinent were taken to new extremes in Punjab. In Bombay in March 1947, even during lulls between episodic stabbings, people were nervous about crossing into each other's 'zones' (Khan 119)

Sensing imminent danger, Mozelle jumps into action and brushes aside Tarlochan's fumbled protest: "But... there's a curfew... Not for Mozelle." (web) she quips. There was not a moment's hesitation in her. Calm, cool, and collected, she advises Tarlochan to disguise himself as a Muslim which Tarlochan foolishly refuses as without his turban Kirpal Kaur would come to know that he has cut off his hair. This leaves the reader disgusted with the foolhardiness of this man. Mozelle, too, is exasperated but she does not waste precious time trying to argue with him. She ventures out in the loose gown that she was wearing. In Bombay, the Jews and the Parsis had a completely different social standing that provided them immunity during the Partition riots. She was astute enough to realise that her gown would make her Jewish identity clear thereby reducing the chances of her being harmed. Hence, when they set out, it is Mozelle who is leading while Tarlochan was so terrified that "...when a leaf stirred, his heart lurched..." (web) She stays calm, unruffled, and has the presence of mind. When they reach Kirpal Kaur's locality, they see the situation is bad. The only time she betrayed being afraid was when she saw two men carrying gunny sacks on their backs from which a thick liquid was dripping. She quivered with fear but held her ground. When they reach Kirpal Kaur, she wastes no time in

pulling off the girl's clothes and putting her gown on her, and opened her hair. Now nobody would suspect Kirpal Kaur to be a Sikh woman. Mozelle, herself was stark naked now. Suddenly there was a pounding on the door. In that desperate moment, Mozelle held on to her wits. Thinking on her feet, she devises a plan. She yanks open the door and races up the stairs. Tarlochan was to follow her swiftly as if hot in pursuit. This ruse would distract the people outside and so it did, particularly the sight of a stark-naked beautiful woman. In addition, this provided the opportunity for Kirpal Kaur to escape. But as fate would have it, the wooden sandals that Mozelle was wearing, slipped on the stairs and she came crashing down: "She fell down the staircase, hitting each hard stair and ramming against the iron railing" (web) hurting herself so badly that "blood bubbled from her mouth" (web) and she dies in a few moments.

Hence, despite being portrayed as a fallen woman, Mozelle redeems herself by saving another person's life and honour. A maverick, who follows her heart, Mozelle is supremely unapologetic about everything about herself. She is no moralist yet in the most testing of times she comes clean while Tarlochan proves to be the moral coward who fails miserably in rising to the occasion. With her presence of mind, she averted the disaster for Kirpal Kaur, though in the process she lost her own life. Sexual violence happened on a mass scale during the Partition. Manto's Mozelle does a yeoman's service by salvaging the life of Kirpal Kaur from such an eventuality. Urvashi Butalia records,

> ...the physical mutilation of their (women's) bodies, the tattooing of their sexual organs with symbols of the other religion... (No mention was made of this kind of violence by anyone-neither the families, nor the state, nor indeed by historians.) And yet, its scale was not small. (Butalia 204)

Manto's deep humanism shines through his work, the greatest of which was produced in the last seven years of his life when he was suffering from serious financial and emotional hardships. Lawsuits were slapped on him and many of his stories were labelled obscene. Admirably, Manto chose to defend himself without the help of any lawyer. Interest has revived in his work which is especially relevant today because we do not seem to have moved away any further from the reality of Partition. We continue to experience similar communal riots from time to time. Butalia further records:

> ...It took 1984 to make me understand how ever-present Partition was in our life, too, to recognize that it could not be so easily put away inside the covers of history books." (Butalia 6)

However, a need to prevent such a disaster need never have arisen if only human beings had learned to live in harmony with each other and with nature. Partition is not a dated event in the history of India. Every time the country witnesses, undergoes, another series of communal riots, it is another Partition. Literature acts as a mirror to society. Aristotle in his most celebrated treatise, *Poetics* emphasizes the imitative nature

of literature. According to him, Literature reflects the actual socio-economic conditions prevailing in a particular society at a particular period which the literary artist has chosen to write about. Aristotle also emphasized the fact that a literary artist has a responsibility towards society which he must perform through his work. He must succeed in making his readers think about what he has depicted so that remedial measures can be taken. Hence the ambit of literature covers the whole gamut of human emotions. Our emotions have remained the same right from the dawn of civilization. Only, they have become more complex and complicated which has resulted in isolating the individual despite the density of the population. Human beings find themselves becoming more and more alienated from one another. Incidents keep happening, life is disrupted for a while and then we gather the threads and get involved once again with the business of life and living. Some are lucky to escape unscathed while others are not so lucky and may become hapless victims of circumstances, created inadvertently by themselves or by others. Some may distinguish themselves when life throws challenges in their way while others may buckle under the pressure and end up in a whimper. Literature is replete with stories spanning the whole range of human emotions and actions. There are stories of human greed, apathy, insensitivity, negligence, and ruthlessness which cause untold misery and suffering and irreparable damage in the lives of countless innocent human beings. At the same time, there are

stories of matchless human courage, fortitude, personal sacrifice, and poise that reinstate our faith in the innate goodness of the human soul. The path toward idealism is a path away from destruction and annihilation. *Mozelle* demonstrates that it passes through altruism.

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